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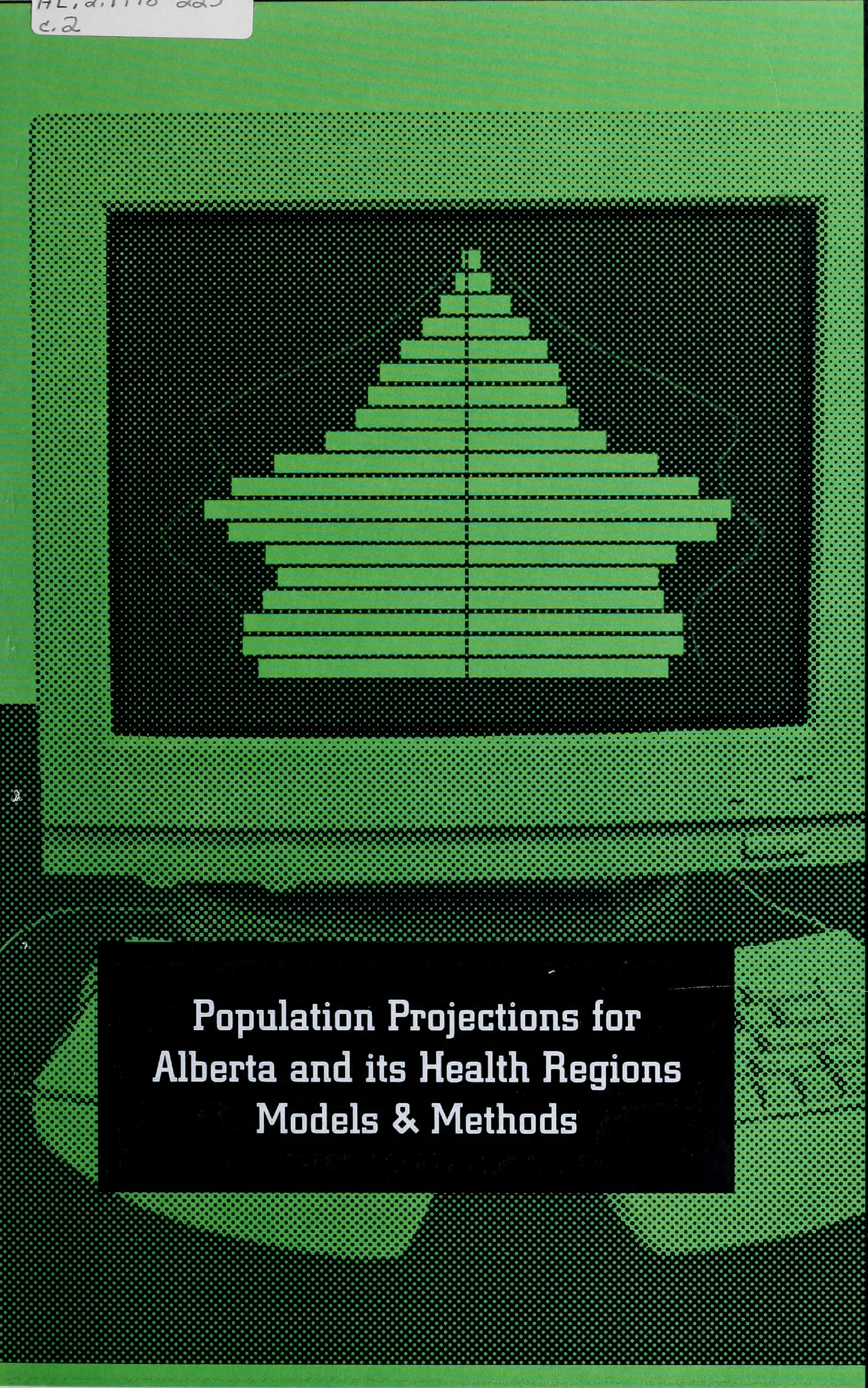

REPORT

Population Projections for Alberta and its Health Regions
Models & Methods

Health Surveillance, Alberta Health

April 1998

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Population Projections for Alberta and its Health Regions: Models and Methods

Prepared by
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March, 1998

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EXECUTIVE SUMMARY

Population projections for Alberta and its 17 health regions (1996 boundaries) were developed for the years 1996 to 2016. For the first time the Alberta Health Care Insurance Plan (AHCIP) Registry File was used to generate a base population as of June 30, 1996. Population projections were developed using the component method which combines analyses of mortality, fertility and migration. Three fertility, one mortality and three migration projections were considered resulting in nine scenarios. For practical purposes, the projection results for a single scenario, the combination of medium mortality, medium fertility and high migration projections, were reported in a companion report entitled ***Population Projections for Alberta and its Health Regions: 1996-2016.***

The current report presents detailed technical information about the development of the projections, including the statistical models underlying the projections for mortality, fertility, and migration.

ACKNOWLEDGMENTS

This final report was prepared by Donald Schopflocher and Yan Jin on behalf of the project team listed below:

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TABLE OF CONTENTS

EXECUTIVE SUMMARY……………………………………………………………………3

ACKNOWLEDGEMENTS……………………………………………………………………4

I General Model *Yan Jin and Donald Schopflocher*……………………………6

II Mortality Projections *Donald Schopflocher and Yan Jin*………………11

III Fertility Projections *Yan Jin and Donald Schopflocher*…………………21

IV Migration Projections *Donald Schopflocher and Yan Jin*………………36

REFERENCES…………………………………………………………………………60

I. GENERAL MODEL

Population projections are forecasts made under certain assumptions of the composition of the population in particular regions at particular points in the future. Projections are developed using information about the existing population, and information about how this population has evolved in the past. The accuracy of population projections depends not only upon the accuracy with which demographic data has been maintained in the past but also upon the extent to which past trends can be estimated and the extent to which they remain predictive of future trends. As well, population change is influenced by political and socioeconomic factors which cannot be accurately measured or projected. As a result, uncertainty around population projections will generally increase over the projection period.

The cohort component method is the most widely used approach for regional population projections (Shryock, Siegel, et al, 1976). It involves the development of projections of the three primary sources of population change: fertility (the rate at which children are born), mortality (the rate at which individuals die), and migration (the rate at which individuals enter or leave the region)[1]. Population projections are created by applying models of these three components to a base year population to project future population change. The advantages of this approach have been discussed and summarized in many studies (e.g. Shryock, Siegel, el., 1976; Jeanine Perreault, 1975; George, Norris, Nault, Loh and Dai, 1994). Principal among these advantages are that the model allows the generation and comparison of multiple population projection scenarios which incorporate differing assumptions about fertility, mortality, or migration.

As a supplement to the *Population Projections for Alberta and its Health Region: 1996-2016*, this report presents the detailed methodology for the projection model

The Basic Equation of the Cohort Component Model

All equations of the Cohort Component Model are derived from the following fundamental equation:

$$P_t = P_{t-1} + B_{t-1,t} - D_{t-1,t} + NM_{t-1,t} \qquad (1)$$

where

P_t is the midyear population (i.e. on June 30) for year t,

P_{t-1} is the midyear population for year t-1,

$B_{t-1,t}$ is the number of live births from midyear of year t-1 to midyear of year t,

$D_{t-1,t}$ is the number of deaths from midyear of year t-1 to midyear of year t, and

$NM_{t-1,t}$ is the net migration from midyear of year t-1 to midyear of year t.

---

[1] The migration component can be further divided into two sub-components, in-migration and out-migration, and each sub-component projected separately. Because of the lack of detailed data, it is treated (viewed) as one component, called net migration.

Equation (1) states that the population at midyear of a year t equals the population at midyear of the previous year plus the number of births during the year minus the number of deaths during the year plus the net number of migrants during the year.

Consider an initial population projection P_1. If the population is known for the previous year P_0 (the 'base' population), and estimates can be provided for $B_{0,1}$, $D_{0,1}$, and $NM_{0,1}$, then equation (1) will yield the desired projections P_1. If estimates are also available for $B_{1,2}$, $D_{1,2}$, and $NM_{1,2}$, equation (1) can be applied again to yield P_2 using the projections P_1 as the base population, and so on.

There are three types of extensions to the basic model that are necessary in order to produce a full set of population projections. The first is an extension which allows the generation of separate projections for age and sex specific sub-populations. This is discussed below.

The second extension is a set of mechanisms which can deliver projections for births, deaths, and migrants. This is typically addressed by developing a separate model for the death or mortality component, the birth or fertility component, and the migration component based upon data collected from previous years. The basic procedure for each of these consists in deriving a descriptive model with a small set of parameters to describe data from previous years, analyzing trends in these parameters over the previous years, projecting these trends into the future, and using these projected parameters and the descriptive model to generate projections for the component of interest. Typically as well, the death component involves the modeling of survival rates (s_t) rather than the raw number of deaths; and the fertility component involves the modeling of fertility rates rather than the raw number of births[2]. Models for each of these components will be presented in a separate chapter.

The third is an extension to allow projections for multiple regions. In theory, separate projections might be produced for each separate region and summed to provide projections for the province as a whole. However, because some regions have very small populations and component models based on these populations might be very unstable, information based on the whole province is used where required to improve the reliability of the projections. Where this has occurred, it is noted in the appropriate chapter.

Incorporating Age-Specific Components

Equation (1) does not provide the age-sex structure of the population under study. In order to obtain the age-sex distribution of the population, Equation (1) is modified and applied to each age sex group. Here, single year of age is considered and the oldest age is defined as 90 years old and over.

---

[2] The migration component may operate on rates, or as in the current case on the raw number of migrants.

1. Populations from age 1 to 89

The population at age x (where x is from 1 year of age to 89 years of age) on June 30 of the year t is determined by the number of survivors from the previous age x-1 on June 30 of the previous year t-1 and the net number of migrants at age x on June 30 of the year t. Since the migration is typically a cumulative measure taken from June 30 of the year t-1 to June 30 of the year t, it is generally assumed that it is distributed evenly across the year. Thus, half of those migrants who are at age x-1 in the year t-1 would be at age x in the year t. In addition, the migration is assumed to occur at the beginning of the year for half of the migrants and at the end of the year for the other half. Hence the survival rate is applied to half of the migrants only. Because it is difficult to obtain separate survival rates for migrants, the survival rate for the migrants is typically assumed to be the same as that for the population under study. In summary, the population at age x for males or for females can be expressed by the equation:

$$P_{x,t} = (P_{x-1,t-1} + \frac{1}{2}NM_{x-1,t-1,t}) \times s_{x,t-1,t} + \frac{1}{2}NM_{x,t-1,t} \qquad (2)$$

where

$P_{x,t}$	is the population at age x on June 30 of the year t,
$P_{x-1,t-1}$	is the population at age x-1 on June 30 of the year t-1,
$NM_{x-1,t-1,t}$	is the net migrants from June 30 of the year t-1 to June 29 of the year t at age x-1,
$s_{x,t-1,t}$	is the projected survival rate from age x-1 to x of the corresponding year.

2. Population at age 90 and over

The key factor in the calculation for the population at age 90 and over is the survival rate, $s_{90+,t-1,t}$, which contains two parts: from age 89 to 90 and from 90 and over to the same age group. The computation is showing in Equation (3):

$$P_{90+,t} = (P_{89,t-1} + \frac{1}{2}NM_{89,t-1,t} + P_{90+,t-1} + \frac{1}{2}NM_{90+,t-1,t}) \times s_{90+,t-1,t} + \frac{1}{2}NM_{90+,t-1,t} \qquad (3)$$

3. Population at age 0

The population at age 0 is calculated by

$$P^{f}_{0,t} = B_{t-1,t} \times p^{f} \times s^{f}_{0,t-1,t} + \frac{1}{2}NM^{f}_{0,t-1,t} \qquad (4.1)$$

$$P^m_{0,t} = B_{t\text{-}1,t} \times (1 - p^f) \times s^m_{0,t-1,t} + \frac{1}{2} NM^m_{0,t\text{-}1,t} \qquad (4.2)$$

where

$B_{t\text{-}1,t}$	is the total number of births from June 30 of the year t-1 to June 29 of the year t.
p^f	is the ratio of female births to the total births,
$s_{0,t\text{-}1,t}$	is the survival rate from newborn to age 0,

and superscripts ^{f} and ^{m} denote female and male respectively.

In turn, births are calculated by

$$B_{t\text{-}1,t} = \frac{1}{2}\left(\sum_{x=15}^{44} P^f_{x,t-1} \times ASFR_{x,t-1} + \sum_{x=15}^{44} P^f_{x,t} \times ASFR_{x,t}\right) \qquad (5)$$

where

$ASFR_{x,t\text{-}1}$	is the age-specific fertility rate for females at age x for the calendar year t-1;and
$ASFR_{x,t}$	is the age-specific fertility rate for females at age x for the calendar year t.

Measures of Demographic Characteristics in the Model

In a full set of projections, a variety of summary measures are typically calculated. The formulas for these are presented below:

1. Births

Since the projected age-specific fertility rates are the rates for a calendar year, the total number of births mentioned above is defined as:

$$B_{t\text{-}1,t} = \frac{1}{2}\left(\sum_{x=15}^{44} P^f_{x,t-1} \times ASFR_{x,t-1} + \sum_{x=15}^{44} P^f_{x,t} \times ASFR_{x,t}\right) \qquad (5)$$

where

$ASFR_{x,t\text{-}1}$	is the age-specific fertility rate at age x for the calendar year t-1.

2. Deaths

The total number of deaths from June 30 of the year t-1 to June 29 of the year t can be obtained from Equation (1):

$$D_{t-1,t} = P_{t-1} + B_{t-1,t} + NM_{t-1,t} - P_t \qquad (6)$$

3. Crude birth rate (CBR)

$$CBR_t = \frac{B_{t-1,t}}{\frac{1}{2}(P_{t-1} + P_t)} * 1000 \tag{7}$$

4. Crude Death Rate (CDR)

$$CDR_t = \frac{D_{t-1,t}}{\frac{1}{2}(P_{t-1} + P_t)} * 1000 \tag{8}$$

5. Natural Increase Rate (NIR)

$$NIR_t = CBR_t - CDR_t \tag{9}$$

6. Age Dependency Ratios

$$\text{Child dependency ratio}_t = \frac{P_{0-14,t}}{P_{15-64,t}} * 100 \tag{10.1}$$

$$\text{Old age dependency ratio}_t = \frac{P_{65+,t}}{P_{15-64,t}} * 100 \tag{10.2}$$

$$\text{Total dependency ratio}_t = \frac{P_{0-14,t} + P_{65+,t}}{P_{15-64,t}} * 100 \tag{10.3}$$

7. Population Median Age (MA_t)

$$MA_t = LB_x + \frac{j}{P_{x,t}} \tag{11.1}$$

where

MA_t is the median age for the year t,

LB_x is the lower boundary of the age x into which the median age must fall,

j is the difference of the half of the total population and the cumulative population up to the age of x-1:

$$j = \frac{1}{2} P_t - \sum_{i=0}^{x-1} P_{i,t} \tag{11.2}$$

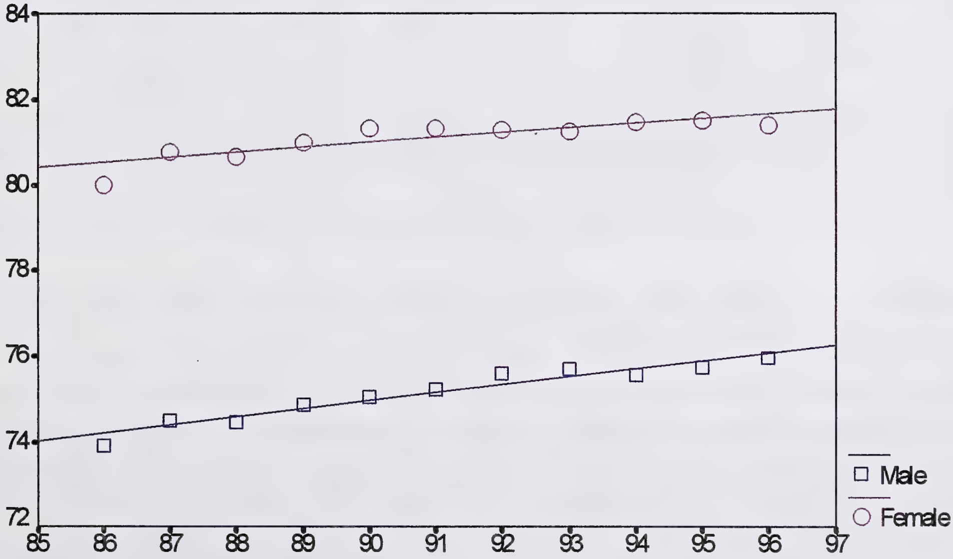
II. MORTALITY PROJECTIONS

Mortality is one of the three most important factors influencing population growth and change. It is also a key factor in projecting future populations. This chapter presents the detailed methodology for mortality projections for the period 1997 to 2016 for Alberta and its health regions.

Historical mortality trends

Population data were obtained from the Alberta Health Care Insurance Plan Registry File and mortality data were obtained from Alberta Vital Statistics for the years 1986 to 1996. Life expectancies and age-specific mortality rates were calculated for the years 1986 to 1996 for Alberta and its health regions. Calculation details can be obtained from Chevalier, S., Choiniere, R. Ferland, R., Pageau, M., and Sauvageau, Y. (1995). For Alberta as a whole, the life expectancies for both females and males have increased over the 11 years (Figure 1). However, regional differences in life expectancy were significant. For example over the eleven year period, female and male life expectancies were 81.55 and 76.37 respectively in the Calgary health region while in the Keeweetinok health region the female life expectancy was 78.29 and the male life expectancy was 72.18.

Figure 1: Life Expectancies by Sex for Alberta 1986-1996



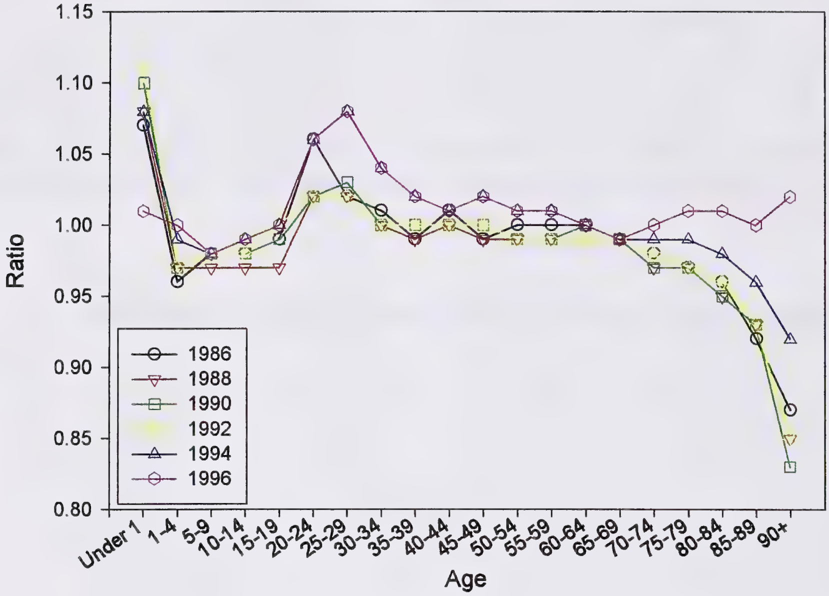
Consequently, the modeling of death rates required the development of both age and gender specific rates and regional differences in these rates.

Methodology

1. Death Rate Corrections

Comparison of population figures derived from the Registry files of the Alberta Health Care Insurance Plan with estimates from Statistics Canada reveal several anomalies, especially for the earlier years under consideration (Figure 2).

Figure 2: Ratios of Alberta Total Population by Year
Statistics Canada Estimates to AHCIP Registry Population



Specifically, the registry underestimates the number of infants less than one year of age and overestimates the number of persons over 70 years of age for the years 1986 to at least 1994. By 1996, however, the estimates appear to be in good agreement. Without correction, this would lead to overestimates of the infant mortality rate, and underestimates of the death rates in seniors. Consequently, a correction was applied as described below. (For the early adult years, the registry again underestimates relative to Statistics Canada figures. We believe that this may be due to specific assumptions about migration, and as is shown elsewhere, migration to Alberta in the mid 1980s and early 1990s was relatively low for the early adult ages. As a result, no corrections were applied to the death rates for young adults).

The ratios (from Figure 2) for the age ranges in question (age 0 and each age from 70-75 to 90+) for each of the years 1986-1996 were modeled as:

$$r_{xt} = \Sigma a_x \, k_t$$

where:

r_{xt} = ratio of Statistics Canada to AHCIP estimated population for each age group for each year

a_x = age specific constants

k_t = level or time(t) parameters

The model was solved using the Singular Value Decomposition (see Lee and Carter, 1992) with two components (or sets of a_x k_t parameters). The death rates for the period 1986 through 1996 for ages 0 and 70+ were adjusted by multiplying them by these modeled ratios.

2. Lee-Carter Model

The Lee-Carter model (Lee & Carter, 1992) was selected to model changes in Age Specific Death Rates. It involves the equation:

$$\ln(m_x) = a_x + b_x k_t$$

where:

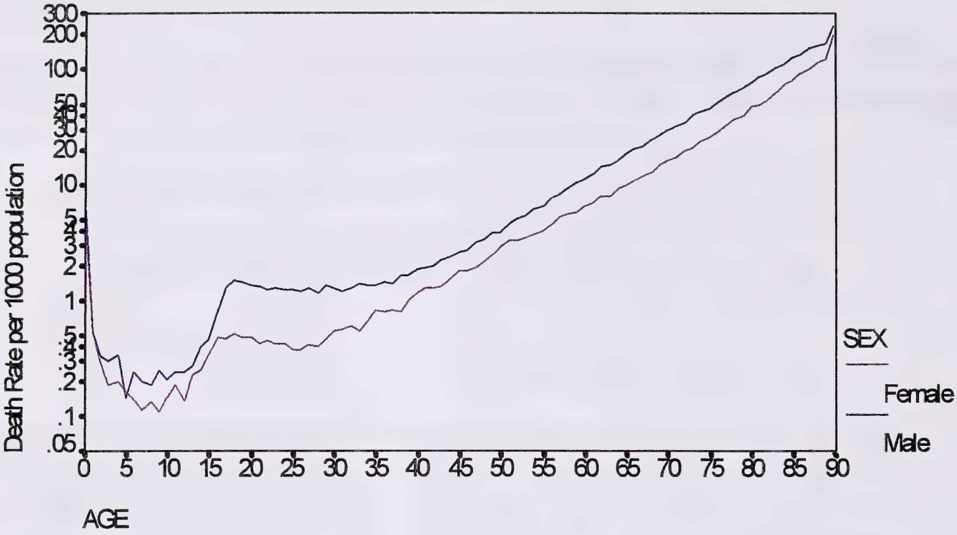
$\ln(m_x)$ = logarithm of the pivotal death rates by age(x)

$a_x + b_x$ = age-specific constants

k_t = a level or time(t) parameter

In the current realization of the model, a_x is set equal to the logarithm of the 1986-1996 average age-specific death rates m_x separately for each sex (Figure 3). The b_x series determines the rate of mortality change at each age. It is set to distribute the decrease in death rate by age according to the age-specific rates observed over the 1986-1996 period for both sexes independently. The k_t are calculated to yield the best linear fit of the model over the time period 1986-1996, also for each sex independently. The $b_x k_t$ component of the model was solved using the procedures of Lee and Carter (1992).

Figure 3: Mean Alberta Death Rate 1986-1996 by Sex



Because of the relatively small length of the series, the b_x series were smoothed by a non-parametric smoother, and remaining negative values (which would have indicated an increasing death rate) were set to 0 (indicating no change from the pivotal death rate). As well, to avoid an anomaly in infant mortality rates, the b_x series for age 0 for each sex was replaced by a b_x calculated over the two sexes combined (see Figures 4 and 5).

Prior to using the model to develop projections, the time trend in the k_t over the period 1986-1996 for each sex separately was calculated. Since the ARIMA procedure as used by Lee and Carter indicated no significant autoregressive component in the series, estimates of the time trend calculated by linear regression were employed (Figure 6).

Figure 4: B parameter for Females

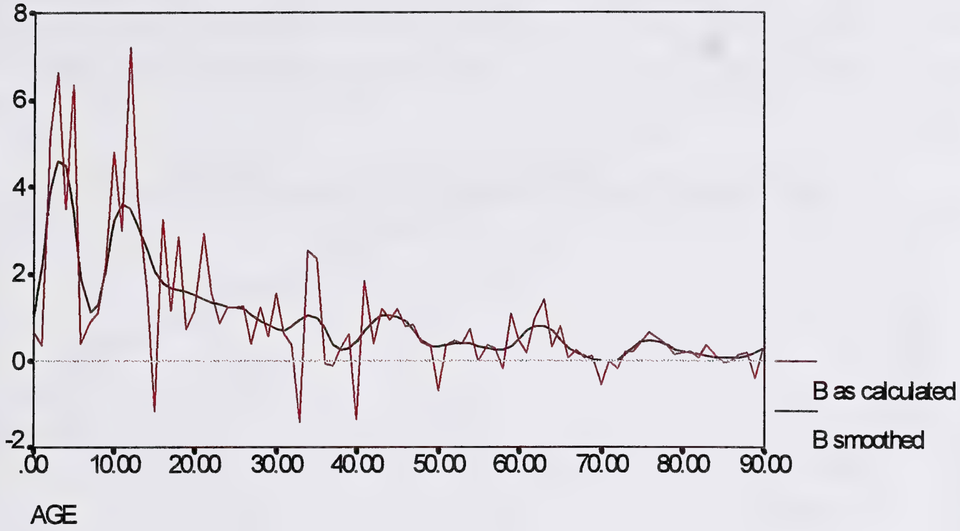
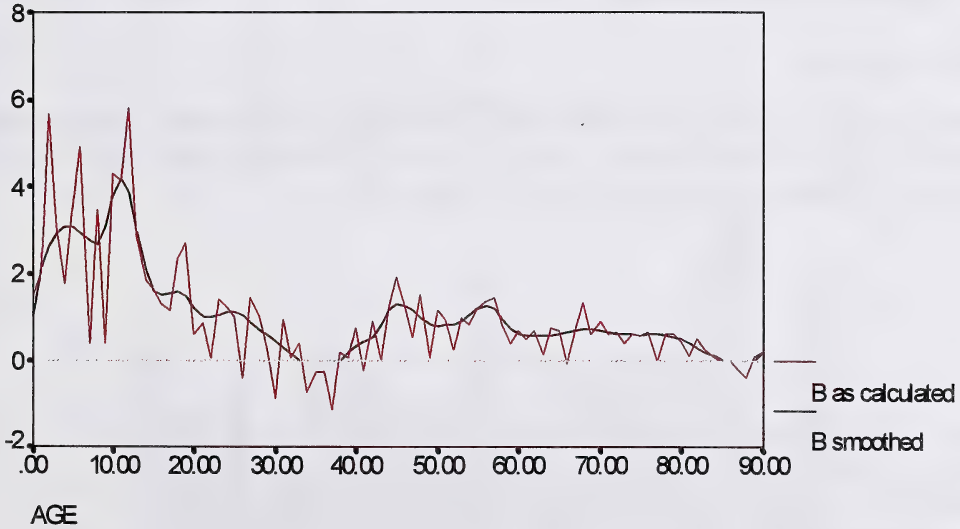


Figure 5: B Parameter for Males



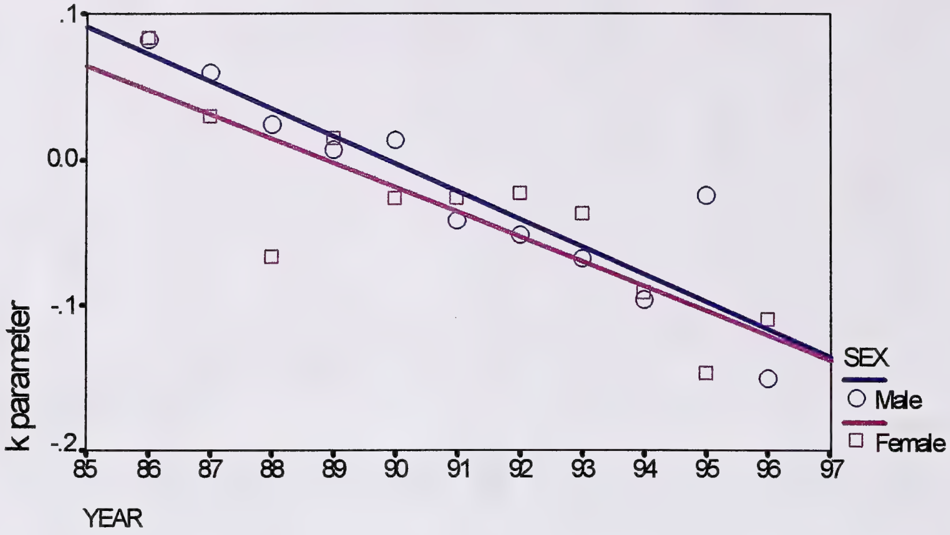


Figure 6: Time Course of K parameter

Together Figures 4 - 6 show that the Age Specific Death Rates declined over the period from 1986 to 1996 (as shown by the downward trend in the K parameter). In addition, the shape of the B parameter curves indicates that this decline was differential, with greater relative decreases at younger ages.

3. RHA Assumptions

As noted previously, life expectancies (and consequently Age Specific Death Rates) differ across the 17 Alberta Health regions. In order to describe these differences in projections, they were modeled (separately for each sex) as:

$$r_{xy} = a_x \, d_y$$

where:

r_{xy} = ratio of a regional death rate for region y to the pivotal death rate across the province for each age group.

a_x = age specific constants

d_y = a constant derived for each region y

This model was solved using the Singular Value Decomposition (see Lee and Carter, 1992). The Age Specific Death Rates for each region were adjusted by multiplying the projections based upon the Lee-Carter model of provincial rates by these modeled ratios. The a_x parameters are shown in Figure 7, while the d_y parameters are shown in Figure 8.

Figure 7: A Parameters for Regional Adjustment by Sex

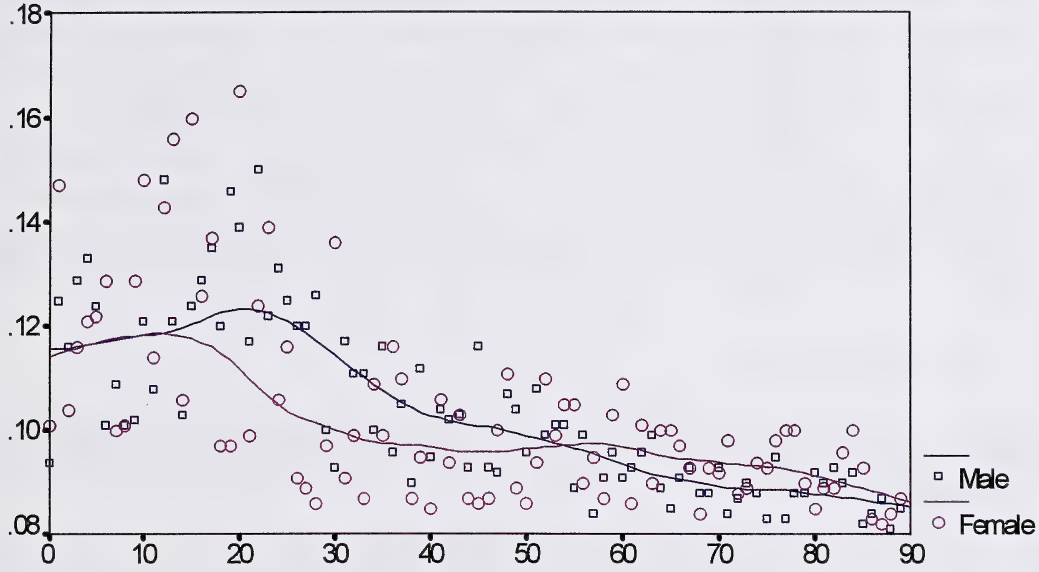
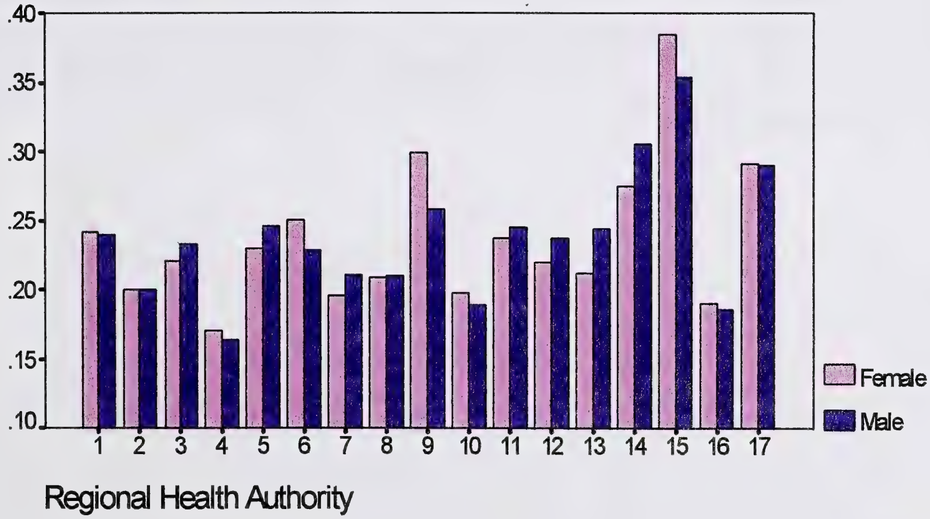


Figure 8: D Parameter by Region and Sex



The general downward trend for parameter a_x by age in Figure 7 for both sexes indicates that the difference in death rates between the regions and the province are concentrated in the lower age groups, while the differences in the d_y parameters in Figure 8 demonstrated that Regions 14, 15, and 17 have generally higher death rates than the provincial rate while the major urban areas (Regions 4 and 10) have generally lower rates.

This model, though it describes the pattern of regional differences in death rate, does not maintain the equivalence between modeled death rates and total number of deaths in the province. Consequently, an alternative procedure was used to develop projections. Specifically, the sex and age specific ratios (r_{xy}) were subjected to a non-parametric smoothing procedure and the resulting smoothed ratios were then multiplied by the provincial sex and age specific ratios to develop regional age and sex specific death rates. This procedure resulted in death rate predictions that maintained the equivalence between modeled death rates and total number of deaths in the province, and also correlated over 0.97 with calculated regional death rates for the period 1986-1996.

4. Projection Procedures

Projections were developed for Alberta by applying the Lee-Carter model to corrected death rates and projecting the k parameter forward in time. Regional adjustments were then applied.

The projection and the 95% confidence intervals on the projection of the k parameter are shown in Figure 9 for both females and males, and the projected life expectancy at birth for Alberta as a whole are shown in Figure 10 for the projections and the 95% confidence intervals. In all cases, the projection is called the medium assumption, the lower 95% confidence interval is called the low assumption and the upper 95% confidence interval is called the high assumption. Barring unforeseen contingencies, the actual life expectancy should fall within the range of the high and low projections with a high degree of certainty.

Figure 9 High, Medium and Low Assumptions for K Parameter

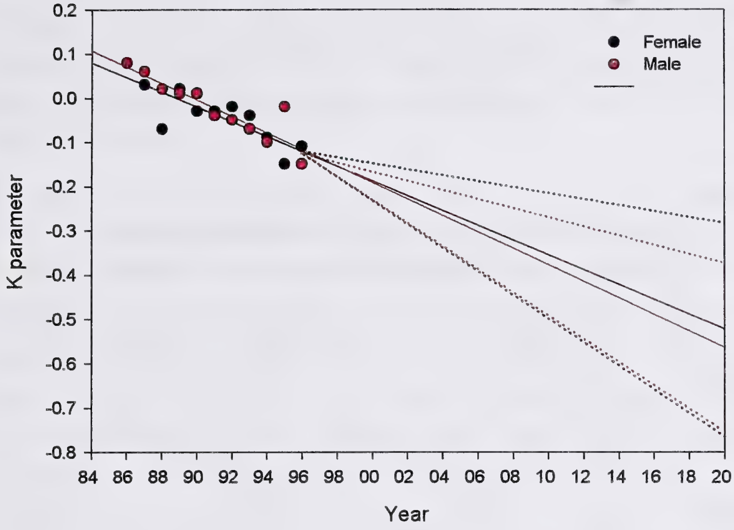


Figure 10: Projected Life Expectancy

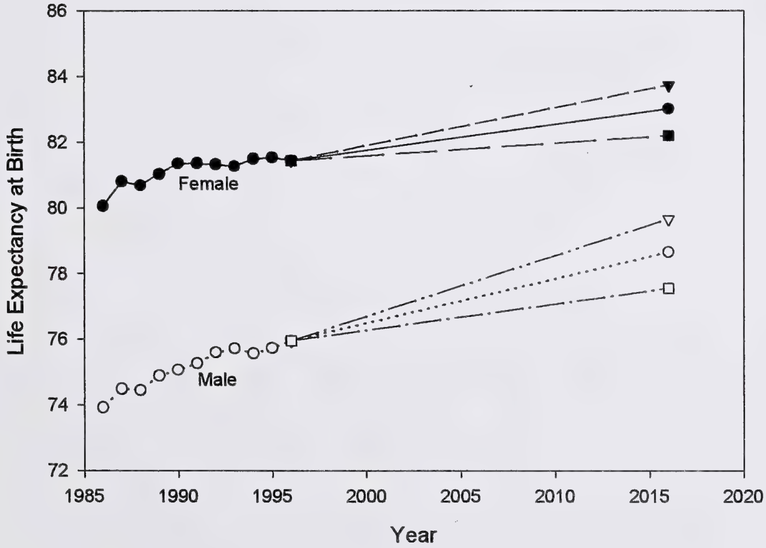


Table 1 compares the current life expectancy at birth assumptions with those used in the Statistics Canada population projections (George, Norris, Nault, Loh & Dai, 1994). The Male projections are in close agreement (except that the current high assumption projects a lower life expectancy). For females, however, the current projections project more modest gains for female life expectancy than do the Statistics Canada projections. We believe that, because the current projections utilize more recent and more complete data than do the national projections, they should be considered more likely.

Table 1: Life Expectancy at Birth Estimates compared to Statistics Canada projections

		High	Medium	Low
Male	Current	79.66	78.65	77.55
	Statistics Canada	81.5	79.0	77.5
Female	Current	83.74	83.01	82.19
	Statistics Canada	86.3	84.3	83.3

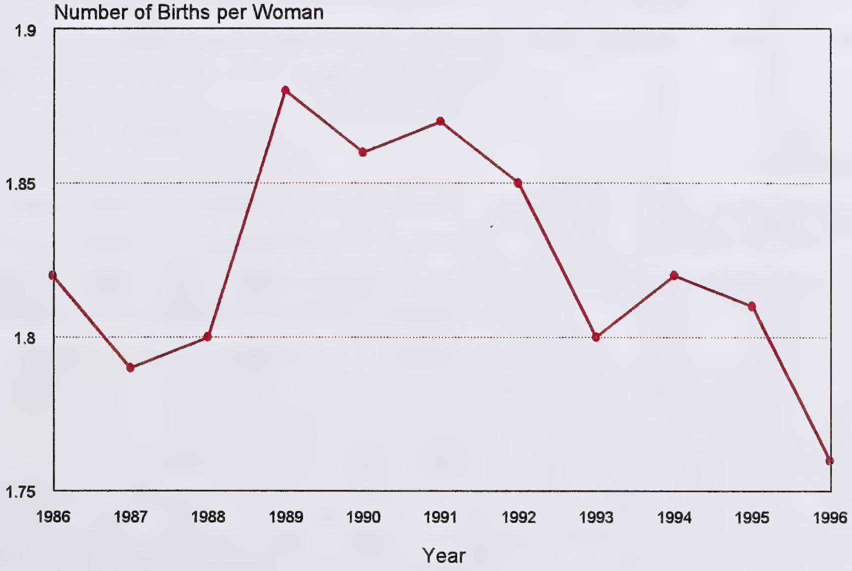
III. FERTILITY PROJECTIONS

Fertility is one of the three most important factors influencing population growth and change. It is also a key factor in projecting future population. This chapter presents detailed methodology for fertility projections for the period 1997 to 2016 for Alberta and its health regions.

Historical fertility trends

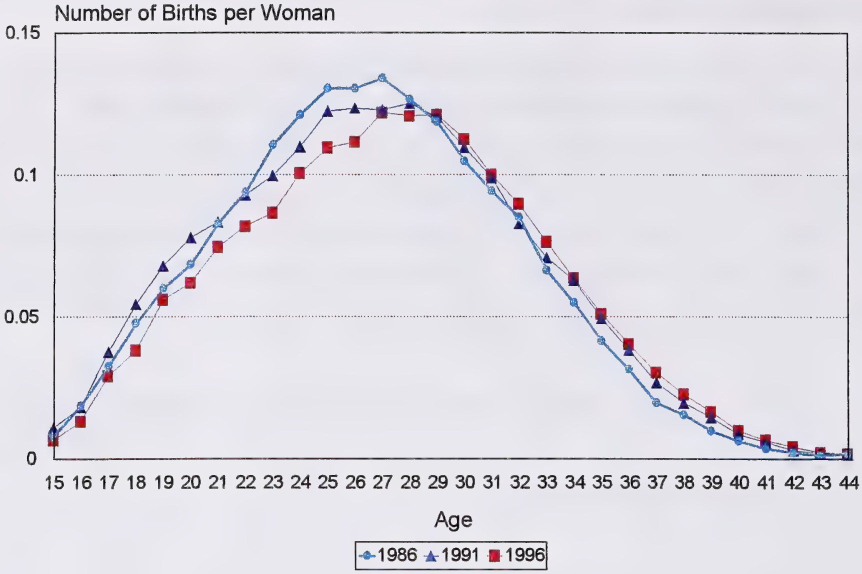
Birth data were obtained from Alberta Vital Statistics and population data were obtained from the Alberta Health Care Insurance Plan Registry File for the years 1986 to 1996. Age-specific fertility rates, total fertility rate (TFR) and mean age of fertility were calculated for the years 1986 to 1996 for Alberta and its health regions. For Alberta as a whole, the TFR was already low and under the replacement level of 2.1 over the 11 years (Figure 1). The TFR was relatively stable and decreased only slightly from 1.82 in 1986 to 1.76 in 1996 (the historical low). However, regional differences in fertility were significant. For example in 1996, the Calgary health region had the lowest TFR of 1.59 and the Northwestern health region had the highest value of 3.41.

Figure 1: Total Fertility Rates for Alberta: 1986-96



The historical trend for age-specific fertility rates at the provincial level showed a shifting pattern toward late fertility (Figure 2). The mean age of fertility for Alberta increased from 27.17 years old in 1986 to 27.92 in 1996.

Figure 2: Age-specific Fertility Rates for Alberta: 1986-96



Methodology

1. Model: Pearson Type III Curve

In the most recent national population projections from Statistics Canada, a four parameter model was used to project future age-specific fertility rates (George, Norris, Nault, Loh and Dai, 1994). The four parameters are the total fertility rate, the mean age of fertility (the first moment), the variance (the second moment), and the third moment about the mean of the fertility distribution or skewness. This model is known as the Pearson Type III Curve. Several detailed studies (Verma, Loh, Dai and Ford, 1994; Verma and Ford, 1992) have demonstrated that the Pearson Type III Curve provided better estimates of births at both national and provincial levels than the Pearson Type I Curve which was employed in the previous national projections. These studies have also shown how to use this model to obtain future age-specific fertility rates.

The mathematical function of the Type III Curve (Verma, Loh, Dai and Ford, 1994) is given below:

$$f(x) = k\left(1+\frac{x-M}{\alpha}\right)^{\gamma\alpha} e^{-\gamma(x-M)} \qquad (1)$$

where
x is the age,
k is a constant (calculated from historical data),
M is the mode,
α and γ are the shape parameters, and
f(x) the age pattern of fertility with $\sum f(x)=1$.

The mode, α and γ are determined by the first moment or mean (μ_1), the variance (μ_2), and third moment about the mean (μ_3):

$$\alpha = \frac{2\mu_2^3}{\mu_3} - \frac{\mu_3}{2\mu_2} \qquad (2)$$

$$\gamma = \frac{2\mu_2}{\mu_3} \qquad (3)$$

$$M = \mu_1 - \frac{1}{\gamma} \qquad (4)$$

Once f(x) is obtained, the age-specific fertility rates (ASFR) can be derived by multiplying TFR with f(x):

$$ASFR(x) = TFR * f(x) \qquad (5)$$

Applying the historical data from 1986 to 1996 to this model, the estimated number of births are very close to the observed number of births for Alberta and its 17 health regions (see Table A3 in Appendices). Thus, this model is employed to project the number of births for each year from 1997 to 2016.

As shown above, the four parameters, TFR, the mean age, the variance and the third moment of the fertility distribution, need to be projected in order to obtain the fertility distribution by age. To keep the model simple, as Statistics Canada did in the national population projections, the constant, the variance and the third moment are assumed to hold unchanged (average of the most recent three years: 1994, 1995 and 1996) during the projection period. Consequently, the two shape parameters α and γ are remained constant for the projection period. Table 1 shows the values of k, μ_2, μ_3, α and γ used in the fertility projections for Alberta and each health region.

Table 1: Assumed Constant Values* of k, μ_2, μ_3, α and γ for Alberta and Each Health Region

Health Region	**k**	**m_2**	**m_3**	**a**	**g**
Chinook	0.0746	29.30	31.44	54.07	1.86
Palliser	0.0808	24.84	25.40	48.06	1.96
Headwaters	0.0727	30.76	5.98	316.26	10.29
Calgary[3]	0.0724	30.86	-0.55	-3449.22	-111.75
RHA 5	0.0809	24.82	27.68	43.94	1.79
David Thompson	0.0771	27.50	33.12	45.06	1.66
East Central	0.0839	23.20	33.31	31.59	1.39
WestView	0.0781	26.77	33.17	42.58	1.61
Crossroads	0.0789	26.30	35.38	38.41	1.49
Capital	0.0718	31.53	11.94	166.36	5.28
Aspen	0.0778	27.35	53.36	27.06	1.03
Lakeland	0.0789	26.34	37.69	36.11	1.40
Mistahia	0.0791	26.27	37.70	35.88	1.39
Peace	0.0770	28.10	53.33	28.67	1.05
Keeweetinok	0.0744	30.71	70.93	25.44	0.87
Northern Lights	0.0767	27.87	33.24	46.13	1.68
Northwestern	0.0704	35.75	123.59	18.95	0.58
Alberta	0.0733	30.29	23.35	78.21	2.59

*: The values for k, μ_2, μ_3 are the average values of 1994, 1995 and 1996.

2. Fertility Assumptions

The three fertility assumptions for Alberta (high, medium and low) from the national projections are adopted in our projections with some modifications. For the rationale of the fertility assumptions, please refer to the national projections documents(Verma, Loh, Dai and Ford, 1994; George, Norris, Nault, Loh and Dai, 1994).

2.1 TFR assumptions

TFR is the most important factor for projecting the number of births. In the medium assumption, the observed value of TFR in 1996 is assumed to remain constant during the projection period. For the high and low assumptions, the values of TFR for Alberta in the national projections are proportionally adjusted because of different base populations and base years. Specifically, the factor of 1.76/1.88 is used. The value of

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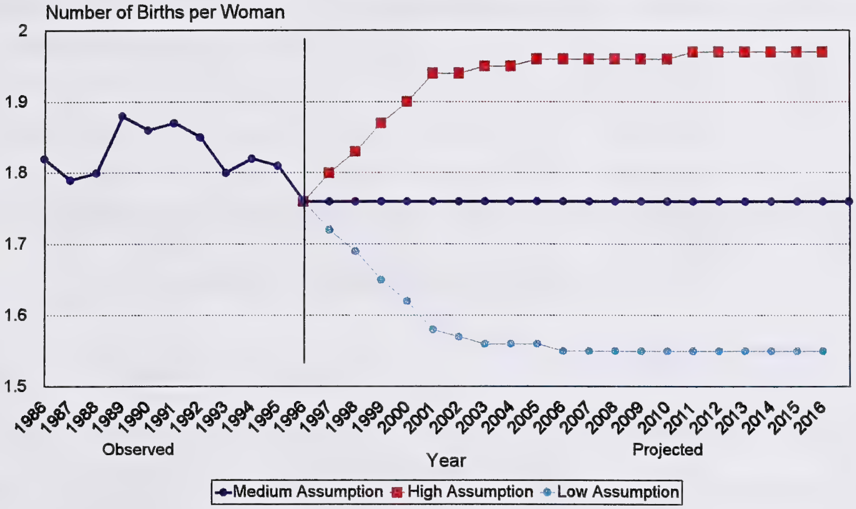
[3] According to the selection criteria for Pearson curves, the Type II Curve may be more appropriate for Calgary than the Type III Curve. However, the difference of the results of the estimated total number of births from both curves is very small by using the past 11 year data (1986-96). In fact, the Type III curve provides a better fit for the age-specific fertility rates in 1996, the most recent year. Therefore, for the uniformity, the Type III curve has been used.

1.76 is the TFR observed in 1996 and the value of 1.88 is the TFR used in the medium assumption for Alberta in the national projections by Statistics Canada. Additionally, in order to have a smooth transition from the observed to the projected TFR, linear interpolation is used for the first 5 years of the projection period. Figure 3 shows the observed and projected TFR for Alberta.

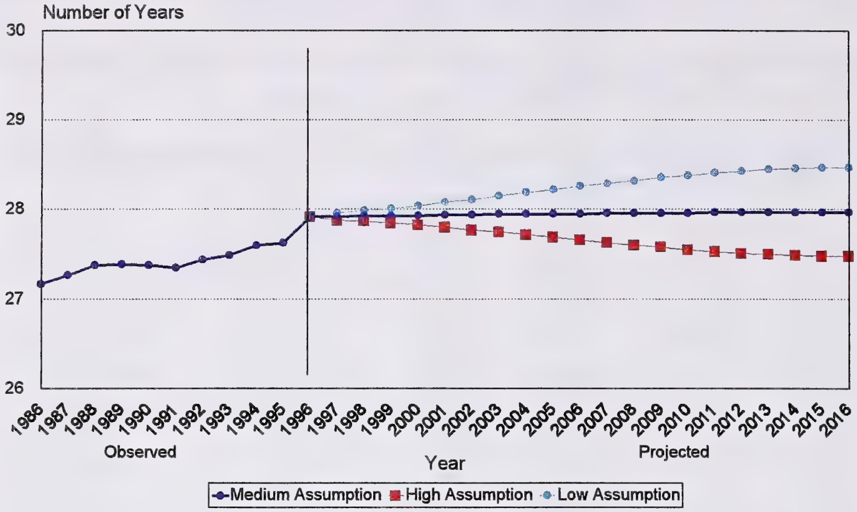
Figure 3: Observed and Projected Total Fertility Rates for Alberta: 1986-2016



2.2 Assumptions of the Mean Age of Fertility

In the fertility projections, the mean age would affect the number of projected births to a lesser degree. Therefore, most projections assume that the most recent available mean age of fertility remains constant during projection periods. However, with the clearly shifting pattern of fertility distribution in Alberta, it is more reasonable to project the changes in the mean age during the projected period. Like the national fertility trend, the Alberta fertility trend also indicated an inverse relationship between the TFR and the mean age. Therefore, the projected mean ages from 1997 to 2016 for Alberta in the national projections are proportionally adjusted to the observed value in 1996. Figure 4 shows the observed and projected trend of the mean age of fertility.

Figure 4: Observed and Projected Mean Age of Fertility for Alberta: 1986-2016



3. Regional Assumptions

Based on the assumption that regional fertility patterns follow the provincial pattern during the projection period, the ratio method of the regional TFR/Mean Age to the provincial TFR/Mean Age is used to obtain projected TFR/Mean Age for each health region. For TFR, the average of the last 5 year (1991 to 1996) ratios is employed. To obtain a smooth transition, the difference between the ratio in 1996 and the average ratio is distributed over the first 5 years of the projection period by an exponential equation. The average ratio is used in the remaining years of the projection period. For the mean age of fertility, the ratio in 1996 is used because of the smooth transition purpose and because the ratio was very stable in the past 11 years.

4. Special Case

The Northwestern health region remained high fertility in the past 11 years. Its TFR was the highest among all regions. For example, the highest value of TFR was 3.80 in 1995 and the lowest of 3.27 in 1988. The assumptions of TFR and mean age discussed above may not be appropriate for this region because with relatively low mortality rates during the same time period, the high fertility rate would decline after a time lag according to the demographic transition theory (Matras, 1973; Petersen, 1972). In fact, the TFR dropped about 10% from 3.80 in 1995 to 3.41 in 1996. Therefore the TFR and mean age assumptions for the Northwestern health region are revised according to the following steps:

(1) The TFR in high, medium and low assumptions is calculated by using the same method for the other regions.

(2) Considered the similarity in terms of socioeconomic conditions and population structure between the Keeweetinok and Northwestern health regions (Parakulam and Jin, 1997), it is assumed, for the medium assumption, that the TFR for the Northwestern health region would be as same as that for the Keeweetinok health region at the end of the projection period, which is 2.6 in 2016.

(3) The TFR of the medium assumption in the intervening years between 1996 and 2016 is linearly interpolated.

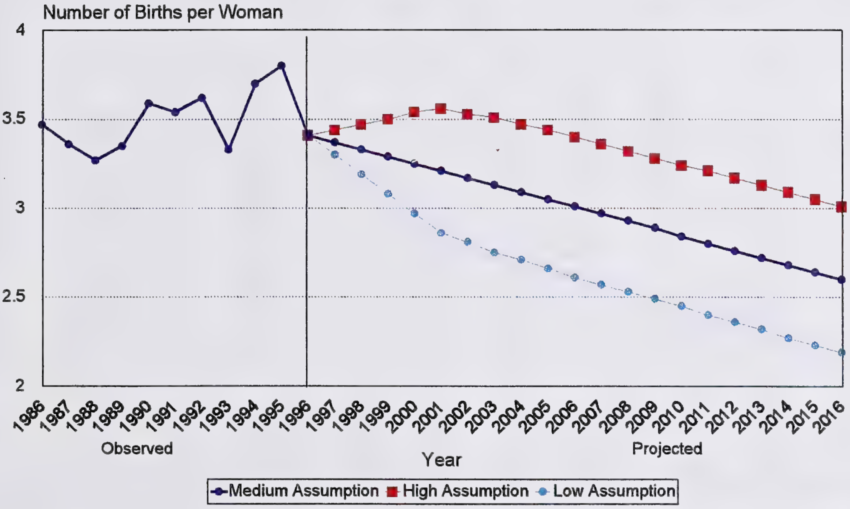
(4) Calculate the difference between the TFR of the medium assumption derived in Step (1) and the TFR derived in Step (3) for each projection year.

(5) The TFR of the high and low assumptions calculated in Step (1) is then adjusted by subtracting the difference derived in Step (4).

(6) The inverse relationship between TFR and the mean age is not hold for the decline of high fertility (reference). Thus, it is assumed that the mean age in 1996 for this region would be hold constant throughout the whole projection period.

The projected TFRs after the adjustments for this region is shown in Figure 5.

Figure 5: Observed and Projected Total Fertility Rates for Northwestern Regional Health Authority: 1986-2016



Appendices to Chapter III

Table A1: Total Fertility Rates (TFRs) by Alberta Health Region: 1986 - 1996

Health Region	Year										
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Chinook	2.14	2.14	2.07	2.25	2.25	2.19	2.26	2.25	2.25	2.24	2.13
Palliser	1.84	1.70	1.80	1.92	1.95	1.90	1.95	1.91	1.88	2.10	1.91
Headwaters	1.88	1.79	1.73	1.87	1.83	1.79	1.84	1.73	1.77	1.66	1.62
Calgary	1.62	1.63	1.63	1.71	1.69	1.67	1.67	1.61	1.64	1.63	1.59
RHA 5	1.97	1.98	1.97	1.96	2.04	2.01	2.01	1.91	1.94	2.03	1.96
David Thompson	2.12	2.00	1.97	2.08	2.04	2.12	2.09	2.12	2.01	2.04	2.01
East Central	1.71	1.76	1.76	1.80	1.83	1.71	1.68	1.72	1.78	1.66	1.60
WestView	1.97	1.89	1.90	1.98	1.94	1.88	1.98	1.82	1.85	1.99	1.86
Crossroads	2.35	2.14	2.16	2.28	2.38	2.28	2.40	2.21	2.22	2.20	2.02
Capital	1.73	1.66	1.72	1.74	1.74	1.79	1.70	1.67	1.66	1.64	1.61
Aspen	2.23	2.18	2.20	2.40	2.22	2.41	2.29	2.21	2.29	2.17	2.17
Lakeland	2.10	2.15	2.04	2.16	2.13	2.13	2.18	2.18	2.14	2.13	2.07
Mistahia[1]	N/A	N/A	N/A	1.97	1.92	2.02	2.03	1.99	2.10	2.10	2.01
Peace[1]	N/A	N/A	N/A	2.47	2.11	2.13	2.13	2.03	2.19	2.24	2.26
Keeweetinok	2.53	2.52	2.33	2.76	2.53	2.65	2.69	2.69	2.86	2.62	2.50
Northern Lights	1.76	1.74	1.96	1.87	2.04	1.81	1.85	1.85	1.76	1.84	1.92
Northwestern	3.47	3.36	3.27	3.35	3.59	3.54	3.62	3.33	3.70	3.80	3.41
Alberta	1.82	1.79	1.80	1.88	1.86	1.87	1.85	1.80	1.82	1.81	1.76

[1] Population data for 1986-88 for the two regions are not correct.

Table A2: Mean Age of Fertility by Albert Health Region: 1986 - 1996

Health Region	Year										
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Chinook	27.10	27.06	27.29	27.35	27.20	27.24	27.36	27.37	27.20	27.34	27.63
Palliser	26.61	26.71	26.83	26.60	27.05	26.89	26.99	27.03	26.99	27.07	27.14
Headwaters	27.60	27.87	27.79	28.10	27.60	27.92	27.95	28.17	28.40	28.02	28.53
Calgary	27.96	28.13	28.14	28.27	28.18	28.21	28.20	28.28	28.42	28.51	28.85
RHA 5	26.81	26.89	27.14	27.05	26.92	26.67	26.80	27.17	27.22	26.96	27.55
David Thompson	26.35	26.31	26.59	26.31	26.45	26.52	26.54	26.74	26.67	26.86	27.11
East Central	26.64	26.68	27.17	26.88	26.90	26.98	26.89	27.32	27.38	27.40	27.42
WestView	26.34	26.48	26.62	26.81	26.57	26.86	27.00	26.94	27.07	27.13	27.43
Crossroads	26.27	26.61	26.27	26.85	26.96	26.69	26.80	26.76	27.07	26.83	27.18
Capital	27.58	27.56	27.75	27.79	27.74	27.62	27.79	27.77	27.97	28.07	28.32
Aspen	26.28	26.35	26.60	26.35	26.39	26.40	26.84	26.88	26.99	26.86	27.19
Lakeland	26.33	26.21	26.30	26.22	26.21	26.49	26.50	26.40	26.71	26.55	26.78
Mistahia	26.13	26.44	26.04	26.18	26.30	25.99	26.44	26.29	26.50	26.21	26.67
Peace	26.17	26.20	25.99	26.32	26.39	26.26	26.58	26.48	26.45	26.33	26.87
Keeweetinok	24.89	25.11	25.45	24.92	25.14	25.05	24.98	26.11	25.90	25.45	26.05
Northern Lights	26.12	26.69	26.43	26.05	26.58	26.66	26.63	26.37	26.60	26.88	26.82
Northwestern	27.25	27.58	27.26	26.76	26.78	26.12	26.37	26.78	26.25	26.57	26.26
Alberta	27.17	27.27	27.38	27.39	27.38	27.35	27.44	27.49	27.60	27.63	27.92

Table A3: Observed and Estimated[1] Number of Births by Alberta Health Region: 1986 - 1996

Health Region	Year										
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1996	1996
						Observed					
Chinook	2452	2423	2320	2467	2443	2354	2402	2344	2323	2292	2150
Palliser	1320	1185	1227	1270	1274	1199	1202	1146	1133	1269	1161
Headwaters	877	835	824	876	881	872	900	857	892	834	846
Calgary	12059	11965	11981	12642	12496	12259	12146	11452	11513	11271	11151
RHA 5	718	702	681	662	689	673	675	639	637	668	650
David Thompson	3065	2839	2758	2854	2811	2875	2828	2833	2620	2611	2585
East Central	1366	1356	1312	1308	1283	1185	1150	1170	1191	1084	1058
WestView	1239	1157	1156	1205	1180	1170	1231	1116	1129	1227	1149
Crossroads	1272	1142	1131	1203	1245	1198	1258	1134	1133	1084	985
Capital	12215	11626	11926	11908	11951	12095	11449	11049	10611	10088	9746
Aspen	1329	1272	1288	1371	1274	1393	1329	1277	1313	1204	1191
Lakeland	1817	1803	1698	1782	1706	1701	1724	1680	1630	1565	1503
Mistahia	1446	1392	1360	1378	1299	1349	1324	1252	1307	1330	1322
Peace	394	380	354	348	352	341	331	312	329	330	331
Keeweetinok	518	513	481	552	511	539	550	542	592	545	529
Northern Lights	773	683	744	701	764	672	670	633	577	574	599
Northwestern	460	444	442	457	475	496	502	467	529	553	518
Alberta	43320	41717	41683	42984	42634	42371	41671	39903	39459	38529	37474
						Estimated					
Chinook	2445	2423	2318	2469	2442	2355	2399	2342	2314	2277	2146
Palliser	1315	1184	1233	1268	1270	1204	1202	1147	1133	1267	1158
Headwaters	872	833	822	881	877	871	901	857	892	837	849
Calgary	12028	11966	11995	12645	12531	12336	12205	11484	11544	11295	11172
RHA 5	720	703	689	665	690	670	673	639	638	665	648
David Thompson	3058	2839	2762	2860	2813	2885	2823	2833	2614	2607	2579
East Central	1364	1353	1318	1309	1290	1190	1149	1167	1196	1085	1054
WestView	1241	1156	1156	1206	1182	1165	1229	1115	1123	1222	1149
Crossroads	1277	1141	1132	1206	1251	1198	1258	1136	1127	1086	977
Capital	12231	11676	11997	11973	12040	12211	11530	11097	10654	10114	9757
Aspen	1326	1269	1281	1374	1281	1388	1332	1279	1318	1199	1189
Lakeland	1812	1804	1696	1779	1712	1697	1716	1686	1621	1559	1498
Mistahia[2]	N/A	N/A	N/A	1385	1306	1347	1331	1253	1304	1328	1316
Peace[2]	N/A	N/A	N/A	348	351	339	332	310	331	329	330
Keeweetinok	515	511	480	552	509	537	545	552	593	546	532
Northern Lights	770	691	749	703	765	674	669	635	578	573	596
Northwestern	472	458	452	466	490	497	507	472	533	557	519
Alberta	43233	41744	41740	43054	42725	42500	41724	39924	39452	38483	37431
						Ratios of Observed to Estimated					
Chinook	1.0028	1.0002	1.0007	0.9991	1.0004	0.9996	1.0013	1.0008	1.0038	1.0065	1.0018
Palliser	1.0039	1.0007	0.9955	1.0015	1.0034	0.9962	1.0002	0.9987	1.0004	1.0015	1.0028
Headwaters	1.0058	1.0018	1.0026	0.9948	1.0042	1.0009	0.9985	1.0002	1.0003	0.9958	0.9960
Calgary	1.0025	0.9999	0.9989	0.9998	0.9972	0.9938	0.9952	0.9972	0.9973	0.9979	0.9981
RHA 5	0.9979	0.9986	0.9887	0.9953	0.9984	1.0039	1.0034	1.0001	0.9991	1.0045	1.0029
David Thompson	1.0023	1.0001	0.9987	0.9980	0.9994	0.9964	1.0017	0.9999	1.0024	1.0015	1.0024
East Central	1.0011	1.0020	0.9957	0.9994	0.9943	0.9955	1.0012	1.0023	0.9955	0.9988	1.0035
WestView	0.9985	1.0009	0.9997	0.9995	0.9981	1.0044	1.0017	1.0005	1.0054	1.0038	0.9999
Crossroads	0.9965	1.0007	0.9989	0.9974	0.9955	0.9996	0.9998	0.9983	1.0057	0.9979	1.0078
Capital	0.9987	0.9957	0.9941	0.9946	0.9926	0.9905	0.9930	0.9957	0.9960	0.9975	0.9988
Aspen	1.0024	1.0027	1.0054	0.9980	0.9945	1.0035	0.9981	0.9987	0.9960	1.0041	1.0015
Lakeland	1.0028	0.9995	1.0014	1.0016	0.9967	1.0024	1.0044	0.9965	1.0056	1.0040	1.0031
Mistahia[2]	N/A	N/A	N/A	0.9946	0.9943	1.0017	0.9950	0.9989	1.0021	1.0017	1.0047
Peace[2]	N/A	N/A	N/A	0.9995	1.0036	1.0044	0.9983	1.0053	0.9940	1.0044	1.0027
Keeweetinok	1.0065	1.0041	1.0019	1.0000	1.0034	1.0046	1.0094	0.9810	0.9978	0.9987	0.9938
Northern Lights	1.0037	0.9880	0.9936	0.9972	0.9992	0.9967	1.0008	0.9974	0.9983	1.0017	1.0055
Northwestern	0.9753	0.9692	0.9778	0.9813	0.9697	0.9973	0.9893	0.9901	0.9931	0.9927	0.9977
Alberta	1.0020	0.9993	0.9986	0.9984	0.9979	0.9970	0.9987	0.9995	1.0002	1.0012	1.0011

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[1] The second moment (μ_2), the third moment (μ_3) and the constant (k) used in the calculations are the average values of the last three years (1994-96).

[2] Population data for 1986-88 for the two regions are not correct.

Table A4: Projected Total Fertility Rates (TFRs) from High Fertility Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	2.18	2.23	2.28	2.33	2.38	2.38	2.40	2.40	2.41	2.41	2.41	2.41	2.41	2.41	2.42	2.42	2.42	2.42	2.42	2.42
Palliser	1.95	1.98	2.02	2.05	2.09	2.09	2.10	2.10	2.11	2.11	2.11	2.11	2.11	2.11	2.12	2.12	2.12	2.12	2.12	2.12
Headwaters	1.66	1.71	1.75	1.80	1.84	1.84	1.85	1.85	1.86	1.86	1.86	1.86	1.86	1.86	1.87	1.87	1.87	1.87	1.87	1.87
Calgary	1.62	1.65	1.68	1.71	1.74	1.74	1.75	1.75	1.76	1.76	1.76	1.76	1.76	1.76	1.77	1.77	1.77	1.77	1.77	1.77
RHA 5	1.99	2.02	2.05	2.08	2.11	2.11	2.12	2.12	2.13	2.13	2.13	2.13	2.13	2.13	2.14	2.14	2.14	2.14	2.14	2.14
David Thompson	2.05	2.09	2.13	2.16	2.20	2.20	2.21	2.21	2.22	2.22	2.22	2.22	2.22	2.22	2.23	2.23	2.23	2.23	2.23	2.23
East Central	1.64	1.68	1.72	1.77	1.81	1.81	1.82	1.82	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.83
WestView	1.89	1.93	1.96	2.00	2.04	2.04	2.05	2.05	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06	2.06
Crossroads	2.08	2.15	2.22	2.29	2.36	2.36	2.37	2.37	2.39	2.39	2.39	2.39	2.39	2.39	2.40	2.40	2.40	2.40	2.40	2.40
Capital	1.64	1.67	1.71	1.74	1.77	1.77	1.78	1.78	1.79	1.79	1.79	1.79	1.79	1.79	1.80	1.80	1.80	1.80	1.80	1.80
Aspen	2.21	2.26	2.30	2.34	2.38	2.38	2.40	2.40	2.41	2.41	2.41	2.41	2.41	2.41	2.42	2.42	2.42	2.42	2.42	2.42
Lakeland	2.11	2.16	2.20	2.25	2.29	2.29	2.30	2.30	2.32	2.32	2.32	2.32	2.32	2.32	2.33	2.33	2.33	2.33	2.33	2.33
Mistahia	2.05	2.08	2.12	2.16	2.19	2.19	2.20	2.20	2.21	2.21	2.21	2.21	2.21	2.21	2.22	2.22	2.22	2.22	2.22	2.22
Peace	2.27	2.29	2.30	2.32	2.33	2.33	2.34	2.34	2.35	2.35	2.35	2.35	2.35	2.35	2.36	2.36	2.36	2.36	2.36	2.36
Keeweetinok	2.57	2.64	2.72	2.79	2.86	2.86	2.88	2.88	2.89	2.89	2.89	2.89	2.89	2.89	2.90	2.90	2.90	2.90	2.90	2.90
Northern Lights	1.93	1.94	1.96	1.97	1.98	1.98	1.99	1.99	2.00	2.00	2.00	2.00	2.00	2.00	2.01	2.01	2.01	2.01	2.01	2.01
Northwestern	3.44	3.47	3.50	3.54	3.56	3.53	3.51	3.47	3.44	3.40	3.36	3.32	3.28	3.24	3.21	3.17	3.13	3.09	3.05	3.01
Alberta	1.80	1.83	1.87	1.90	1.94	1.94	1.95	1.95	1.96	1.96	1.96	1.96	1.96	1.96	1.97	1.97	1.97	1.97	1.97	1.97

Table A5: Projected Total Fertility Rates (TFRs) from Medium Fertlity Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	2.13	2.14	2.15	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16	2.16
Palliser	1.91	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90
Headwaters	1.63	1.64	1.65	1.66	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68	1.68
Calgary	1.59	1.59	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58	1.58
RHA 5	1.95	1.94	1.93	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92	1.92
David Thompson	2.01	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
East Central	1.60	1.61	1.62	1.63	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64	1.64
WestView	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85	1.85
Crossroads	2.04	2.07	2.09	2.12	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15	2.15
Capital	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
Aspen	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17	2.17
Lakeland	2.07	2.07	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
Mistahia	2.01	2.00	2.00	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99	1.99
Peace	2.23	2.20	2.17	2.14	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Keeweetinok	2.52	2.54	2.56	2.58	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60	2.60
Northern Lights	1.89	1.87	1.84	1.82	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Northwestern	3.37	3.33	3.29	3.25	3.21	3.17	3.13	3.09	3.05	3.01	2.97	2.93	2.89	2.84	2.80	2.76	2.72	2.68	2.64	2.60
Alberta	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76

Table A6: Projected Total Fertility Rates (TFRs) from Low Fertlity Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	2.09	2.05	2.02	1.98	1.95	1.93	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
Palliser	1.87	1.83	1.78	1.74	1.70	1.69	1.68	1.68	1.68	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
Headwaters	1.60	1.57	1.55	1.53	1.51	1.50	1.49	1.49	1.49	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48
Calgary	1.55	1.52	1.49	1.45	1.42	1.41	1.41	1.41	1.41	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
RHA 5	1.91	1.86	1.81	1.77	1.72	1.71	1.70	1.70	1.70	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69	1.69
David Thompson	1.97	1.92	1.88	1.84	1.80	1.79	1.78	1.78	1.78	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
East Central	1.57	1.55	1.52	1.50	1.48	1.47	1.46	1.46	1.46	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
WestView	1.82	1.78	1.74	1.70	1.66	1.65	1.64	1.64	1.64	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63
Crossroads	2.00	1.98	1.96	1.95	1.93	1.92	1.91	1.91	1.91	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89	1.89
Capital	1.57	1.54	1.51	1.48	1.45	1.44	1.43	1.43	1.43	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
Aspen	2.12	2.08	2.03	1.99	1.95	1.94	1.92	1.92	1.92	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91	1.91
Lakeland	2.03	1.99	1.95	1.91	1.87	1.86	1.85	1.85	1.85	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84	1.84
Mistahia	1.96	1.92	1.88	1.83	1.79	1.78	1.77	1.77	1.77	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76	1.76
Peace	2.18	2.11	2.04	1.97	1.90	1.89	1.88	1.88	1.88	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86	1.86
Keeweetinok	2.47	2.43	2.40	2.37	2.34	2.32	2.31	2.31	2.31	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30	2.30
Northern Lights	1.85	1.79	1.73	1.67	1.61	1.60	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59	1.59
Northwestern	3.30	3.19	3.08	2.97	2.86	2.81	2.75	2.71	2.66	2.61	2.57	2.53	2.49	2.45	2.40	2.36	2.32	2.27	2.23	2.19
Alberta	1.72	1.69	1.65	1.62	1.58	1.57	1.56	1.56	1.56	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55	1.55

Table A7: Projected Mean Age of Fertility from High Fertlity Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	27.58	27.57	27.55	27.53	27.50	27.47	27.45	27.42	27.39	27.36	27.33	27.30	27.28	27.25	27.23	27.21	27.20	27.19	27.18	27.18
Palliser	27.09	27.08	27.06	27.04	27.01	26.98	26.96	26.93	26.90	26.87	26.84	26.81	26.79	26.76	26.74	26.72	26.71	26.70	26.69	26.69
Headwaters	28.50	28.49	28.47	28.45	28.42	28.38	28.36	28.33	28.30	28.27	28.24	28.21	28.19	28.16	28.14	28.11	28.10	28.09	28.08	28.08
Calgary	28.83	28.82	28.80	28.78	28.74	28.71	28.69	28.66	28.63	28.60	28.57	28.53	28.51	28.48	28.46	28.44	28.43	28.42	28.41	28.41
RHA 5	27.50	27.49	27.47	27.45	27.42	27.39	27.37	27.34	27.31	27.28	27.25	27.22	27.20	27.17	27.15	27.13	27.12	27.11	27.10	27.10
David Thompson	27.06	27.05	27.03	27.01	26.98	26.95	26.93	26.90	26.87	26.84	26.81	26.78	26.76	26.73	26.71	26.69	26.68	26.67	26.66	26.66
East Central	27.37	27.36	27.34	27.32	27.29	27.26	27.24	27.21	27.18	27.15	27.12	27.09	27.07	27.04	27.02	27.00	26.99	26.98	26.97	26.97
WestView	27.38	27.37	27.35	27.33	27.30	27.27	27.25	27.22	27.19	27.16	27.13	27.10	27.08	27.05	27.03	27.01	27.00	26.99	26.98	26.98
Crossroads	27.13	27.12	27.10	27.08	27.05	27.02	27.00	26.97	26.94	26.91	26.88	26.85	26.83	26.80	26.78	26.76	26.75	26.74	26.73	26.73
Capital	28.28	28.27	28.25	28.23	28.20	28.17	28.15	28.12	28.09	28.06	28.03	28.00	27.97	27.94	27.92	27.90	27.89	27.88	27.87	27.87
Aspen	27.14	27.13	27.11	27.09	27.06	27.03	27.01	26.98	26.95	26.92	26.89	26.86	26.84	26.81	26.79	26.77	26.76	26.75	26.74	26.74
Lakeland	26.72	26.71	26.69	26.67	26.64	26.62	26.60	26.57	26.54	26.51	26.48	26.45	26.43	26.40	26.38	26.36	26.35	26.34	26.33	26.33
Mistahia	26.61	26.60	26.58	26.56	26.54	26.51	26.49	26.46	26.43	26.40	26.37	26.34	26.32	26.29	26.27	26.25	26.24	26.24	26.23	26.23
Peace	26.81	26.80	26.78	26.77	26.74	26.71	26.69	26.66	26.63	26.60	26.57	26.54	26.52	26.49	26.47	26.45	26.44	26.43	26.42	26.42
Keeweetinok	25.98	25.97	25.95	25.94	25.91	25.88	25.86	25.83	25.80	25.77	25.75	25.72	25.70	25.67	25.65	25.63	25.62	25.61	25.60	25.60
Northern Lights	26.76	26.75	26.73	26.71	26.68	26.66	26.64	26.61	26.58	26.55	26.52	26.49	26.47	26.44	26.42	26.40	26.39	26.38	26.37	26.37
Northwestern	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26
Alberta	27.88	27.87	27.85	27.83	27.80	27.77	27.75	27.72	27.69	27.66	27.63	27.60	27.58	27.55	27.53	27.51	27.50	27.49	27.48	27.48

Table A8: Projected Mean Age of Fertility from Medium Fertility Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	27.62	27.63	27.63	27.63	27.64	27.64	27.65	27.65	27.65	27.65	27.66	27.66	27.66	27.66	27.67	27.67	27.67	27.67	27.67	27.67
Palliser	27.13	27.14	27.14	27.14	27.15	27.15	27.16	27.16	27.16	27.16	27.17	27.17	27.17	27.17	27.18	27.18	27.18	27.18	27.18	27.18
Headwaters	28.54	28.55	28.55	28.55	28.56	28.56	28.57	28.57	28.57	28.57	28.58	28.58	28.58	28.58	28.59	28.59	28.59	28.59	28.59	28.59
Calgary	28.87	28.88	28.88	28.88	28.89	28.89	28.90	28.90	28.90	28.90	28.91	28.91	28.91	28.91	28.92	28.92	28.92	28.92	28.92	28.92
RHA 5	27.54	27.55	27.55	27.55	27.56	27.56	27.57	27.57	27.57	27.57	27.58	27.58	27.58	27.58	27.59	27.59	27.59	27.59	27.59	27.59
David Thompson	27.10	27.11	27.11	27.11	27.12	27.12	27.13	27.13	27.13	27.13	27.14	27.14	27.14	27.14	27.14	27.14	27.14	27.14	27.14	27.14
East Central	27.41	27.42	27.42	27.42	27.43	27.43	27.44	27.44	27.44	27.44	27.45	27.45	27.45	27.45	27.46	27.46	27.46	27.46	27.46	27.46
WestView	27.42	27.43	27.43	27.43	27.44	27.44	27.45	27.45	27.45	27.45	27.46	27.46	27.46	27.46	27.47	27.47	27.47	27.47	27.47	27.47
Crossroads	27.17	27.18	27.18	27.18	27.19	27.19	27.20	27.20	27.20	27.20	27.21	27.21	27.21	27.21	27.22	27.22	27.22	27.22	27.22	27.22
Capital	28.32	28.33	28.33	28.33	28.35	28.35	28.36	28.36	28.36	28.36	28.37	28.37	28.37	28.37	28.38	28.38	28.38	28.38	28.38	28.38
Aspen	27.18	27.19	27.19	27.19	27.20	27.20	27.21	27.21	27.21	27.21	27.22	27.22	27.22	27.22	27.23	27.23	27.23	27.23	27.23	27.23
Lakeland	26.76	26.77	26.77	26.77	26.78	26.78	26.79	26.79	26.79	26.79	26.80	26.80	26.80	26.80	26.81	26.81	26.81	26.81	26.81	26.81
Mistahia	26.65	26.66	26.66	26.66	26.67	26.67	26.68	26.68	26.68	26.68	26.69	26.69	26.69	26.69	26.70	26.70	26.70	26.70	26.70	26.70
Peace	26.85	26.86	26.86	26.86	26.87	26.87	26.88	26.88	26.88	26.88	26.89	26.89	26.89	26.89	26.90	26.90	26.90	26.90	26.90	26.90
Keeweetinok	26.02	26.03	26.03	26.03	26.04	26.04	26.05	26.05	26.05	26.05	26.06	26.06	26.06	26.06	26.07	26.07	26.07	26.07	26.07	26.07
Northern Lights	26.80	26.81	26.81	26.81	26.82	26.82	26.83	26.83	26.83	26.83	26.84	26.84	26.84	26.84	26.85	26.85	26.85	26.85	26.85	26.85
Northwestern	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26
Alberta	27.92	27.93	27.93	27.93	27.94	27.94	27.95	27.95	27.95	27.95	27.96	27.96	27.96	27.96	27.97	27.97	27.97	27.97	27.97	27.97

Table A9: Projected Mean Age of Fertility from Low Fertlity Assumption by Alberta Health Region: 1997 - 2016

Health Region	Year																			
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Chinook	27.66	27.69	27.71	27.74	27.78	27.81	27.84	27.88	27.91	27.95	27.98	28.01	28.05	28.07	28.10	28.12	28.14	28.15	28.16	28.16
Palliser	27.17	27.20	27.21	27.24	27.28	27.31	27.34	27.38	27.41	27.45	27.48	27.51	27.55	27.57	27.60	27.62	27.64	27.65	27.66	27.66
Headwaters	28.58	28.61	28.63	28.66	28.71	28.74	28.77	28.81	28.84	28.88	28.91	28.94	28.99	29.01	29.04	29.06	29.08	29.09	29.10	29.10
Calgary	28.91	28.94	28.96	29.00	29.04	29.07	29.10	29.14	29.17	29.22	29.25	29.28	29.32	29.34	29.37	29.39	29.42	29.43	29.44	29.44
RHA 5	27.58	27.61	27.63	27.66	27.70	27.73	27.76	27.80	27.83	27.87	27.90	27.93	27.97	27.99	28.02	28.04	28.06	28.07	28.08	28.08
David Thompson	27.14	27.16	27.18	27.21	27.25	27.28	27.31	27.35	27.38	27.42	27.45	27.48	27.52	27.54	27.57	27.59	27.61	27.62	27.63	27.63
East Central	27.45	27.48	27.50	27.53	27.57	27.60	27.63	27.67	27.70	27.74	27.77	27.80	27.84	27.86	27.89	27.91	27.93	27.94	27.95	27.95
WestView	27.46	27.49	27.51	27.54	27.58	27.61	27.64	27.68	27.71	27.75	27.78	27.81	27.85	27.87	27.90	27.92	27.94	27.95	27.96	27.96
Crossroads	27.21	27.24	27.26	27.29	27.33	27.35	27.38	27.42	27.45	27.49	27.52	27.55	27.59	27.61	27.64	27.66	27.68	27.69	27.70	27.70
Capital	28.37	28.40	28.42	28.45	28.49	28.52	28.55	28.59	28.62	28.66	28.70	28.73	28.77	28.79	28.82	28.84	28.86	28.87	28.88	28.88
Aspen	27.22	27.25	27.27	27.30	27.34	27.37	27.39	27.43	27.46	27.50	27.53	27.56	27.60	27.62	27.65	27.67	27.69	27.70	27.71	27.71
Lakeland	26.80	26.83	26.85	26.88	26.92	26.95	26.98	27.01	27.04	27.08	27.11	27.14	27.18	27.20	27.23	27.25	27.27	27.28	27.29	27.29
Mistahia	26.69	26.72	26.74	26.77	26.81	26.84	26.86	26.90	26.93	26.97	27.00	27.03	27.07	27.09	27.12	27.14	27.16	27.16	27.17	27.17
Peace	26.89	26.92	26.94	26.97	27.01	27.04	27.07	27.11	27.14	27.18	27.20	27.23	27.27	27.29	27.32	27.34	27.36	27.37	27.38	27.38
Keeweetinok	26.06	26.09	26.11	26.13	26.17	26.20	26.23	26.27	26.29	26.33	26.36	26.39	26.43	26.45	26.47	26.49	26.51	26.52	26.53	26.53
Northern Lights	26.84	26.87	26.89	26.92	26.96	26.99	27.02	27.05	27.08	27.12	27.15	27.18	27.22	27.24	27.27	27.29	27.31	27.32	27.33	27.33
Northwestern	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26	26.26
Alberta	27.96	27.99	28.01	28.04	28.08	28.11	28.15	28.19	28.22	28.26	28.29	28.32	28.36	28.38	28.41	28.43	28.45	28.46	28.47	28.47

IV. MIGRATION PROJECTIONS

Migration is one of the three most important factors influencing population growth and change. It is also a key factor in projecting future populations. This report presents the detailed methodology for migration projections for the period 1997 to 2016 for Alberta and its Health regions.

Methodology

Data were combined from three sources to derive net migration figures. Population figures consisted of mid-year single-year-of-age totals for each of 17 Regional Health Authorities in Alberta for each of the years 1986 to 1996 inclusive, as recorded in the Stakeholder Registry of the Alberta Health Care Insurance Plan. The total number of deaths by age and sex for each region for each year were assembled from the Vital Statistics Registry administered by Alberta Registries. Similarly, number of births for each region and each year were assembled from the Vital Statistics Registry.

The net migration figures were calculated by age and sex for each region, and calendar year period by the residual method. That is, for each region net migration is calculated as the number of individuals at an age for the current year minus the number of individuals at the previous year of age in the previous year adjusted for the number of deaths of individuals at that age in the current year. Adjustments involving the number of births are necessary to account for age 0 migrations. As well, a modified calculation is required to account for the open ended nature of the final age category (age 90+).

Unfortunately, the resulting three-way table (years of age by calendar year by Regional Health Authority) contains some uncertainties of interpretation. The individual entries show net migration into or out of each Regional Health Authority (for each age group for each calendar year), but the origin of migration cannot be determined from the current data. That is, the net migrations at the regional level may be to or from either other regions or places outside Alberta. If the table is aggregated across all regions to form a single year-of-age by calendar year table for Alberta as a whole, however, the figures do represent net migration to or from Alberta.

The current analysis attempts to take this uncertainty into consideration by first modeling the external migration trends over time for Alberta as a whole. To estimate the values of the cells in the original three way table, these modeled estimates of external migration are then allocated to each region in proportion to each region's population. To the extent that this is an accurate allocation, residuals formed by subtracting these estimates from the raw totals will represent internal migration and are available for a separate modeling process. If a misallocation has occurred, this misallocation would be corrected in the analysis of residuals, although now the analysis of residuals would represent internal migration and misallocation of external migration together and might be more difficult to interpret. Of course, the accuracy of the proportional allocation assumption cannot be directly assessed with the current data.

For purposes of analysis, then, the three-way table of net migration figures (year-of-age by calendar year by region) was aggregated into two-way tables. First, net migration data for Alberta as a whole by year-of-age and by calendar year was analyzed to determine the pattern of external migration into/out of Alberta as it fluctuated by year over the past decade. Next, the external migration as modeled by this procedure was allocated to each region in proportion to each region's population, and deviations from the actual migration figures were calculated. A two-way table of year of age by Regional Health Authority residuals considered over the entire 10 year period was analyzed to model internal migration (and correct for misallocation of external migration). Finally, the residuals from the combination of these two modeled components were aggregated into an Regional Health Authority by Year table and examined to determine whether there were temporal trends in internal migration/reallocation that had not been captured by the model.

After smoothing, made necessary by anomalies in the data, each of these tables were subjected to direct singular value decomposition to determine the nature of the components necessary to adequately describe the data patterns in the table. In brief, each two-way table is described as a sum of individual components, where each component consists of a particular pattern of migration which varies proportionally over the other dimension of the table. Varying numbers of these components may be required to adequately describe the pattern of data in each table. (For a technical description, see Appendix A).

The pattern of components are then interpreted in light of their utility for migration projections, and deficiencies and proposed corrections are noted. Finally, the results of these analyses are combined with three migration scenarios utilized by Statistics Canada in Canadian Provincial population projections to project migration figures for each Regional Health Authority for each year of age for the period 1997-2016.

Alberta Migration Patterns 1986-1995

1. Net Migration to Alberta by Year-of-age and Calendar year

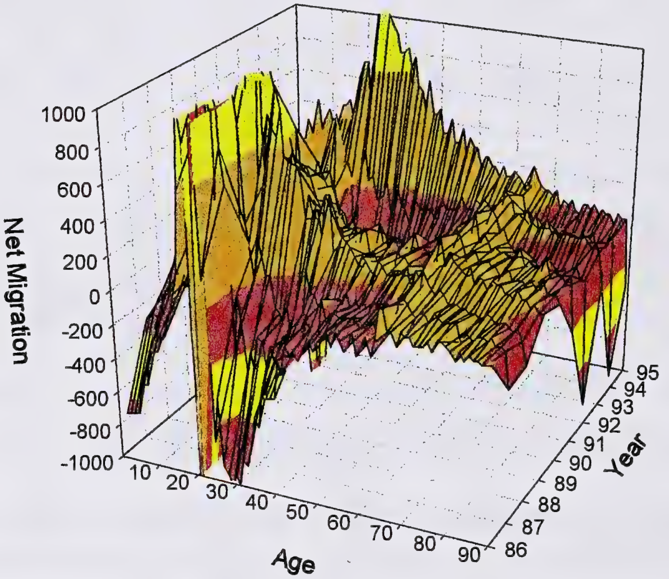
The first table analyzed contained net migration data for Alberta as a whole by year-of-age and by calendar year.

Certain data anomalies were readily apparent. First, the raw data appear to show high positive net migrations for young children of age 0 to 1. This is most likely due to a lag in the registration of young children into the Alberta Health Care Insurance Plan rather than a real migration. As a consequence, the net migration data for children aged 0 and 1 was eliminated from further analysis. Second, particularly for the calendar period 1986 to 1990, the data show a high negative net migration at age 21 despite high positive net migrations at ages 19 and 20, and at ages 22 and 23. Prior to the institution of a unique lifetime identifier for Health Care Insurance registration, young adults were typically registered under their parents' plan until age 21. This pattern of data most likely reflects a business practice in which young adults were de-registered at age 21 and re-registered under a different number when they next required medical services. The lag between these processes could account for the anomalous data.

A variety of strategies to correct this anomaly were examined. The most effective of these was a complex smoothing strategy[4] applied first to net migration at each age for each year independently and then for each year at each age independently.

Figure 1 presents the raw net migration data aggregated across region in the form of a three dimensional space while figure 2 presents the smoothed data.

Figure 1: Uncorrected Net Migration by Age and Year



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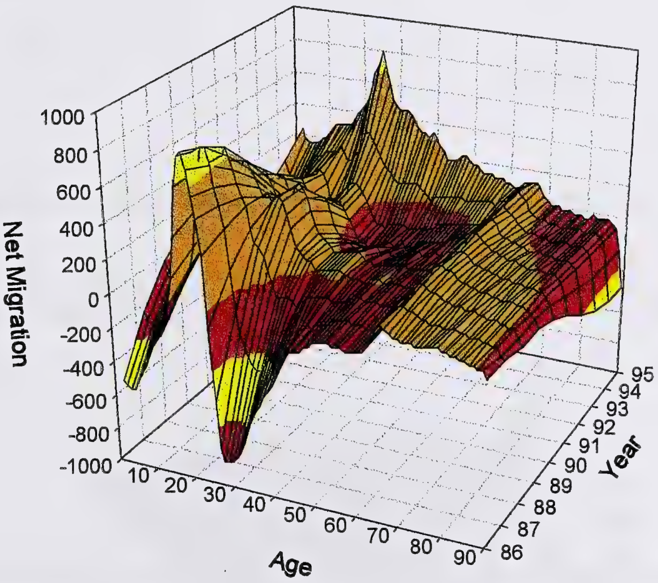
[4] The T4253H smoother starts with a running median of 4, which is centered by a running median of 2. It then re-smoothes these values by applying a running median of 5, a running median of 3, and hanning (running weighted averages). Residuals are computed by subtracting the smoothed series from the original series. This whole process is then repeated on the computed residuals. Finally, the smoothed residuals are computed by subtracting the smoothed values obtained the first time through the process.

Figure 2: Smoothed Net Migration by Age and Year



A singular value decomposition of this smoothed surface was performed. Two components were examined. Each of these components represents a separate additive portion of the overall variation in the surface, and, when added together, approximate the smoothed surface in figure 2 to a high degree of accuracy. Each of these two components are presented below as follows: First, the three-dimensional diagram which reconstructs the surface from the single component alone is presented. Second, pairs of two-dimensional plots are presented which allow a more detailed examination of relationships: the component loadings for year-of-age are plotted against year-of-age while the component loadings for calendar year are plotted against calendar year. The surface in the first diagram is reconstructed by multiplication (at each age, for each year, the appropriate component loadings are multiplied together and then multiplied by a constant determined by the singular value decomposition). The plot of component loadings for year of age can be understood as an average profile of the reconstructed figure, as seen from the diagram presented first from the two dimensional view which shows only net migration and age. Similarly, the plot of component loadings for calendar year can be understood as an average profile from the two dimensional view which shows only net migration and calendar year. The first component is presented in figures 3 -5.

Figure 3: First Component Reconstruction of Net Migration

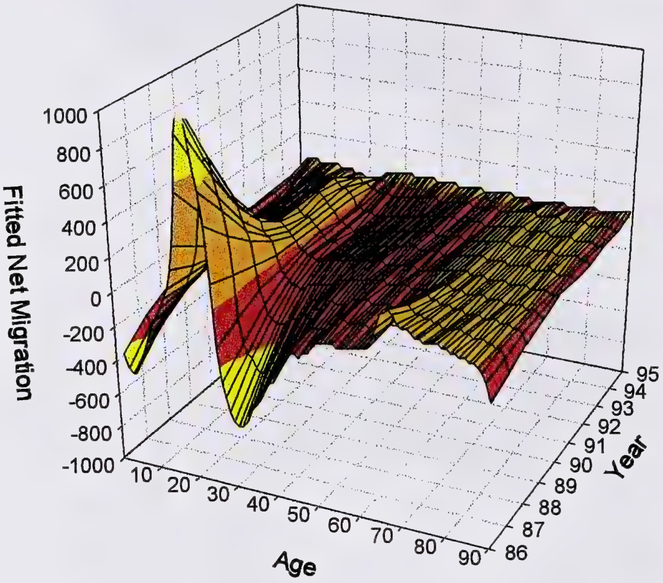


Figure 4: External Migration Model Loadings for Component 1 by Year of age

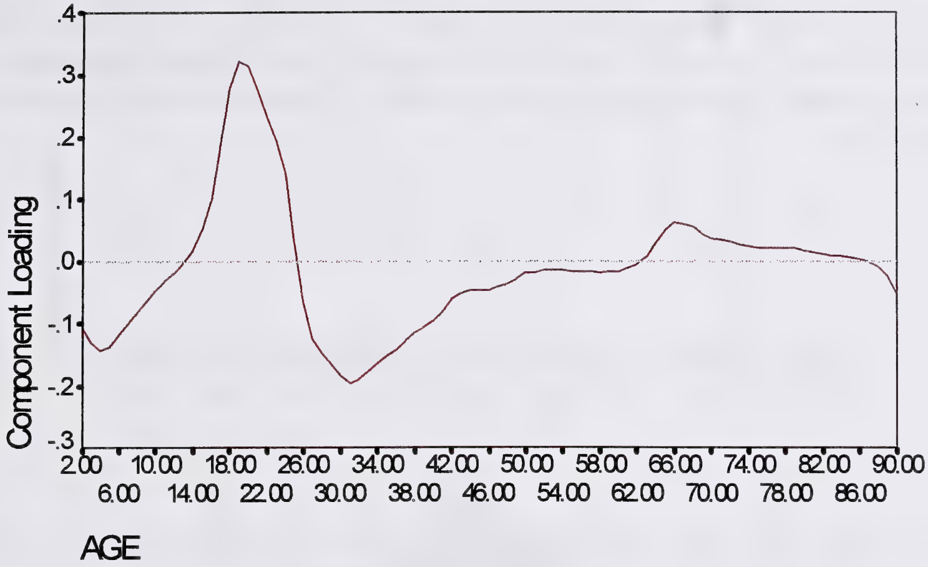


Figure 5: External Migration Model Loadings for Component 1 by Calendar Year

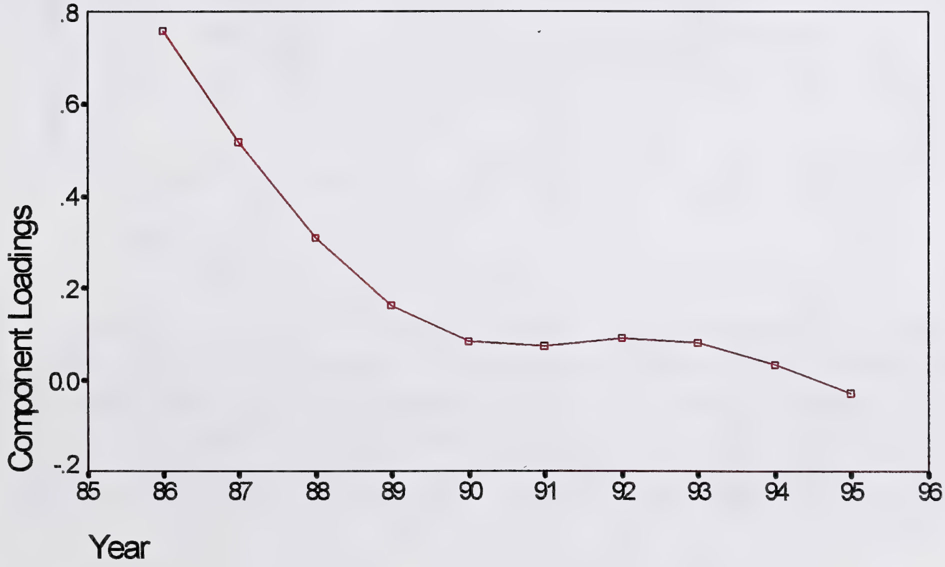


Figure 4 identifies a tendency for in-migration by individuals in the later teenage years and early twenties. It also identifies a tendency for this in-migration to be associated with a net out-migration of younger persons and individuals in the later twenties and early thirties. Figure 5 shows that this tendency was strong in the 1980s but had declined by 1990 to the point that it did not appear to be important in describing the migration surface. The second component of the net migration surface is presented in figures 6 to 8.

Figure 6: Second Component Reconstruction of Net Migration

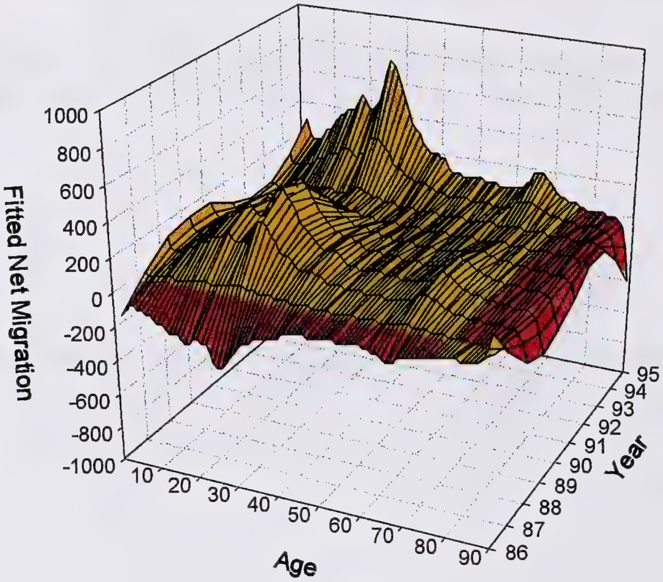


Figure 7: External Migration Model Loadings for Component 2 by Year of age

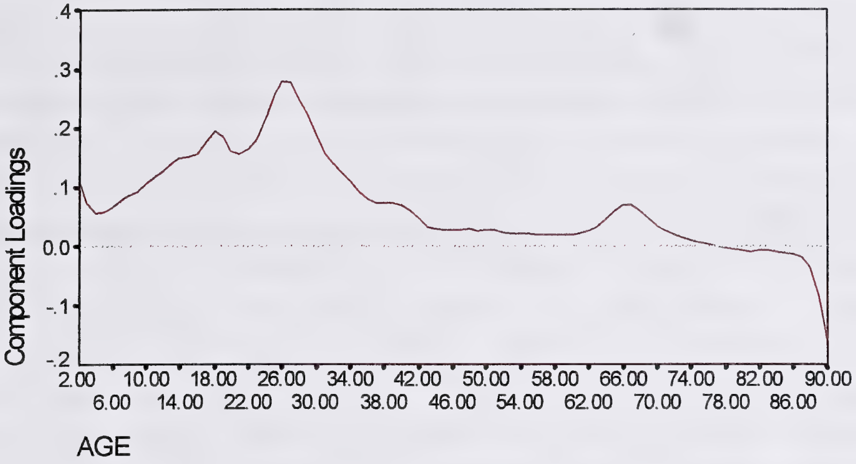


Figure 8: External Migration Model Loadings for Component 2 by Calendar Year

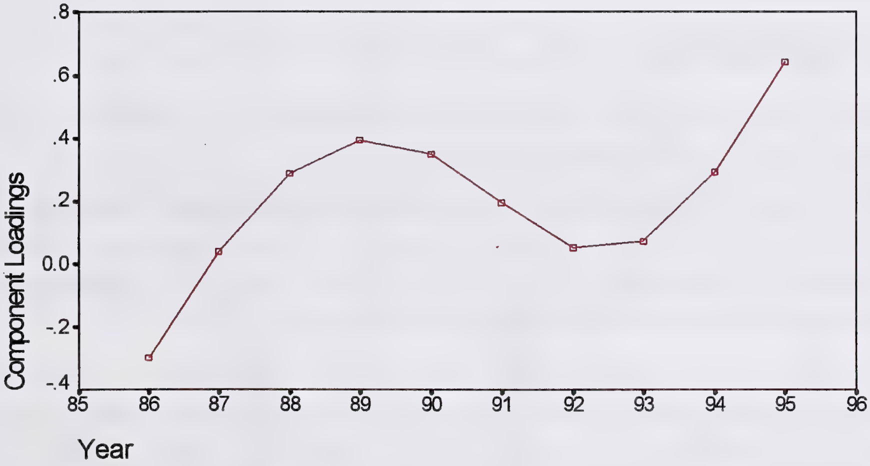


Figure 7 describes a pattern of migration that is highest for individuals in the late twenties and early thirties, intermediate for teens and preteens, and generally slightly positive for other ages. Figure 8 shows that this component was prominent from 1988 until 1991 and then resurgent in the latest two years. The negative loading for 1986 indicates that the pattern was reversed (i.e. net out-migration at these ages rather then in-migration). The sharp decline at age 90 is very likely an artifact of the data and may represent an undercounting of deaths at very advanced ages rather than a net out-migration of the very elderly.

It is clear from the small number of years for which migration data is available and the variability in the migration surface that projection of trends forward in time will be speculative. The analysis does indicate several stable features about Alberta migration, however, that will prove useful in constructing migration scenarios. First, when net in-migration occurs, it is primarily in four age groups: young adults in the late teenage years and early twenties, adults in the late twenties and early thirties, children (whom it might be reasonable to conclude are the offspring of in-migrating adults in their twenties and thirties), and individuals between 65 and 70 years of age (who, it may seem reasonable to suppose, are recent retirees). Second, over the period examined, there has been a definite shift in patterns of in-migration from large influxes of young (late teens , early 20s) adults to large influxes of older (late 20s, early 30s) adults. What is uncertain is whether this shift is a long term one, or whether it is related to underlying socio-economic factors for the specific period in question. It does seem likely that the first component might show a resurgence if net in-migration to Alberta increased markedly in the future. Finally, for other age groups, a net out-migration evident in the 1980s has gradually shifted into a net in-migration in the mid-1990s. (Mathematically, this last trend is represented by a subtle interaction of the small and medium loadings for both components).

2. Regional Differences

The previous analysis gives a representation of the pattern of migration to and from the province of Alberta for the previous decade. It does not, however, give an indication of the pattern of migration to and from the 17 Alberta Regional Health Authorities. There are problems associated with adequately modeling these patterns. As previously noted, net migration figures when tabulated by RHA do not give estimates of migration to and from locations outside Alberta to each of the RHAs; rather, the disaggregated figures conflate migration to/from outside Alberta with migration between RHAs within Alberta.

Consequently, the following strategy was adopted. First, the net migrations by age group and calendar year (as estimated by the model described above) were ‘allocated’ to each of the RHAs in proportion to their population (derived from a ten year population composite). Second, a set of residuals were calculated as the difference between the original net migration figures and these estimated values. Third, the three way table of residuals was aggregated across years to yield a table of residual migrations by age and RHA over the decade as a whole. Fourth, a singular value decomposition of this two way residual matrix was performed. To the extent that the proportional allocation of external migration is correct, then the components of the residual matrix will represent internal migration. To the extent that misallocation has occurred, then the components will also include a component which corrects this misallocation.

A 3 component singular value decomposition of the two way age by RHA table of residuals was sufficient to reproduce the data. Because there is no satisfying intrinsic ordering to Alberta's 17 health regions, a three dimensional graph like those of Figures 1 and 2 is not presented for the two way net migration table years-of-age by region collapsed across calendar years. However, for each of the three components, pairs of loading diagrams are presented below. Figures 9 and 10 present the first component loadings.

Figure 9:
Stable Internal Migration Model Loadings for Component 1 by Year of age

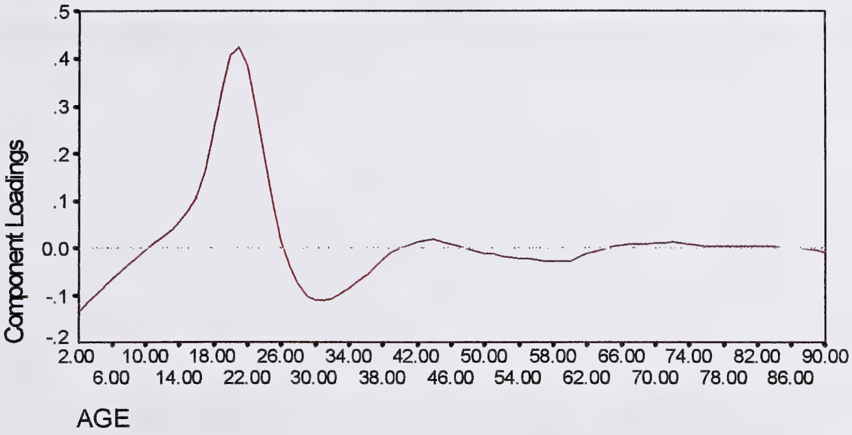
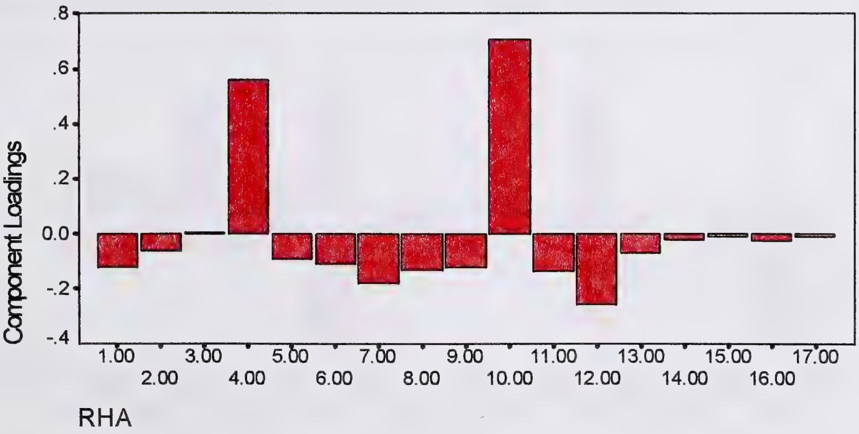


Figure 10: Stable Internal Migration Model Loadings for Component 1 by RHA



Recall that the components presented here represent a combination of internal migration between RHAs within Alberta and the errors of having allocated in- (or out-) migrants to each RHA proportional to population. Figure 9 shows a strong migration peak for the young adult years. Figure 10 shows that this pattern is relevant to RHAs 4 and 10 (Calgary and Edmonton respectively) and is reversed (i.e. representing out-migration) for all other RHAs. This indicates that younger adults migrate disproportionately to Alberta's major urban centres, and may indicate as well a tendency for these young adults to migrate from other RHAs to the urban areas. Figures 10 and 11 show loadings for the second component of the year-of-age by region migration table.

Figure 11:
Stable Internal Migration Model Loadings for Component 2 by Year of age

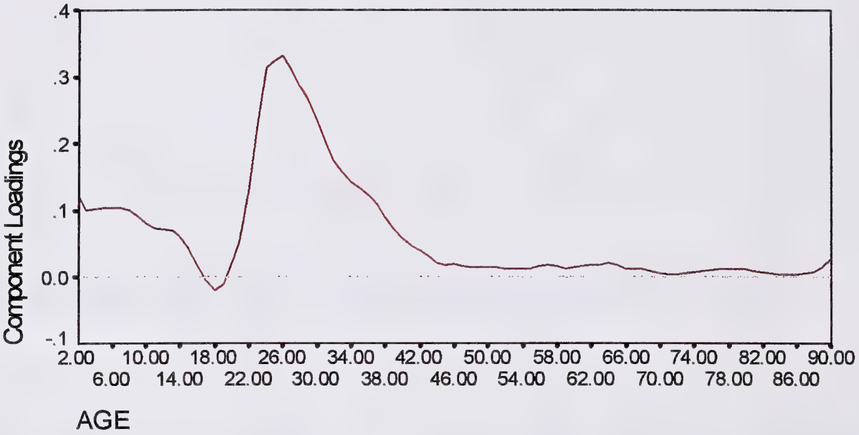


Figure 12: Stable Internal Migration Model Loadings for Component 2 by RHA

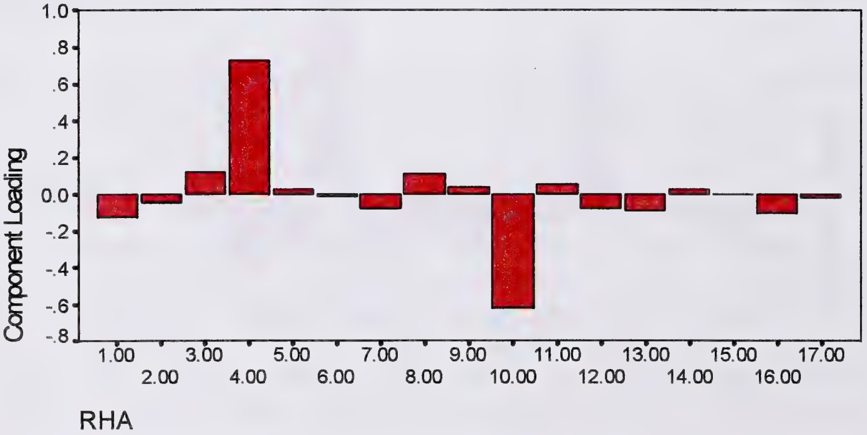


Figure 11 shows a peak for individuals in their later twenties and a secondary peak for young children. Figure 12 indicates that over the period of the study, there was a large inflow of individuals in these age groups to RHA 4 (Calgary) combined with an outflow of individuals in these age groups from RHA 10 (Edmonton). It is unclear whether this represents an actual migration from Edmonton to Calgary or a misallocation of external migrants to Edmonton (rather than Calgary) or some combination of these two features. This is of particular importance in the context of the yearly migration trends into Alberta because of the recent increase in the number of in-migrants to Alberta in these age groups (as represented in figures 6 - 8). Figures 13 and 14 show loadings for the third component.

Figure 13:
Stable Internal Migration Model Loadings for Component 3 by Year of age

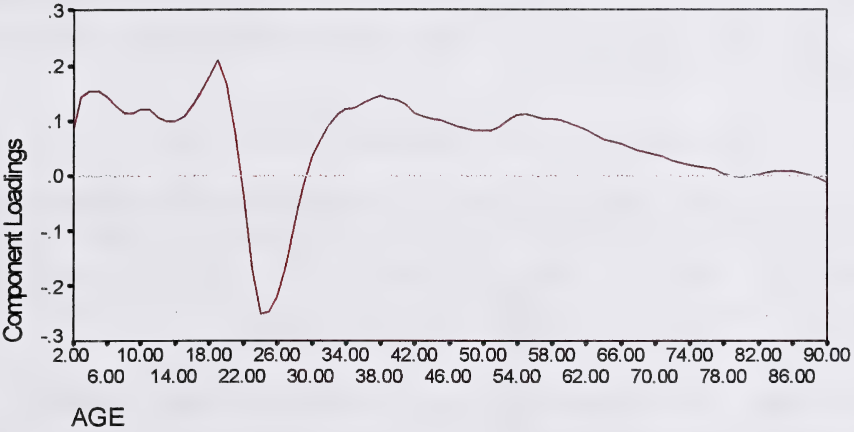
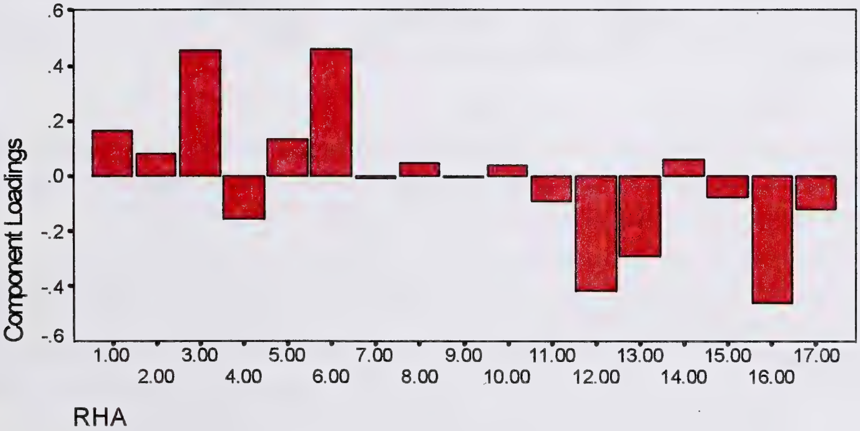


Figure 14: Stable Internal Migration Model Loadings for Component 3 by RHA



The main features of Figure 13 are a large negative peak for individuals in the mid twenties and lesser positive peaks for older adults and young people. Figure 14 shows a definite geographic trend for this migration components such that it appears to show a relative outflow of adults in the mid-twenties and inflow of older adults and younger children to the southern RHAs (exclusive of Calgary) and an opposite flow (inflow of mid-twenties adults and outflow of older adults and children) from northern RHAs. RHAs in Central Alberta do not show this migration trend.

Combining the information from all three of these components supports the following general description of regionally based migration patterns over the past decade: migrations of young adults tend to occur primarily to the major metropolitan areas of Alberta from both outside and inside Alberta. There has, however, been a net inflow to Calgary and outflow from (or lack of in-flow to) Edmonton of individuals in the later twenties and early thirties. In addition, there is a tendency for adults in their mid twenties to migrate from southern to northern RHAs, while the movement is reversed for older adults and young children.

3. Time Trend Adjustments to Internal Migration/Reallocation

The previous analyses derived a pattern of external migration to Alberta as a whole, and then, on the assumption that the external migration had been proportionally allocated to the regions by population, described the patterns of internal migration across the full decade. What remains outside the domain of the model, to this point, is a representation of any temporal trends in internal migration.

As a third stage in the modeling process, this component was considered. First, the internal migration model described above was allocated to each region and age group in equal proportion to the number of years under consideration. Given both the estimates of external migration and the estimates of stable internal migration thus formed, another set of residuals were formed. These were collapsed over age groups to form an RHA by Calendar year table, which was then analyzed by singular value decomposition. Two components proved sufficient to describe the structure in this table.

As in the previous analysis, the components are presented in pairs of diagrams; in this case one represents the temporal trend while the other represents the degree to which each RHA is affected. Figures 15 and 16 present the first component.

Figure 15: Variable Internal Migration Model Loadings for Component 1 by Year

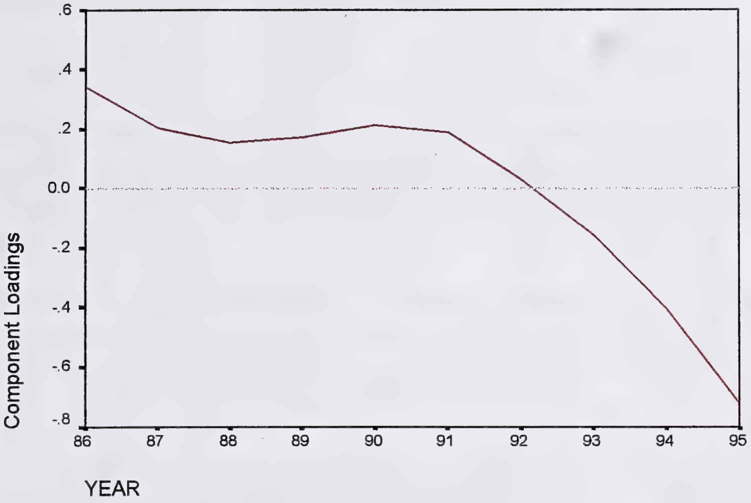
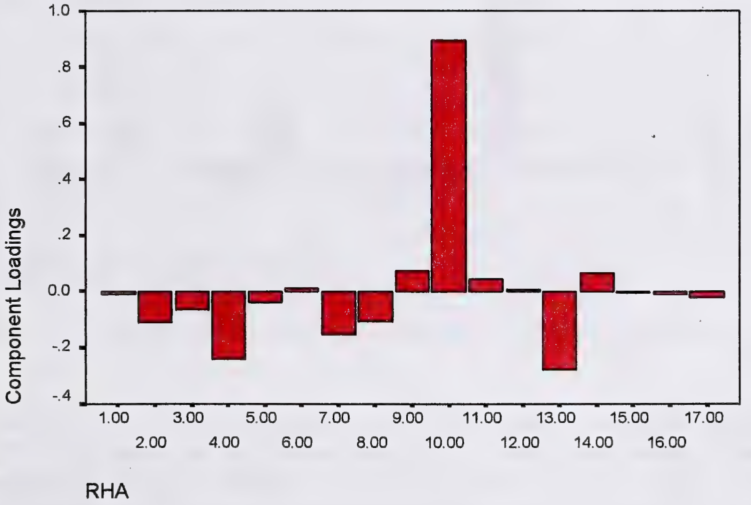


Figure 16: Variable Internal Migration Model Loadings for Component 1 by RHA



Figures 15 and 16 show a component which primarily describes a pattern of internal migration/ reallocation for RHA 10 (Edmonton) such that an early net inflow in the late 1980s has given way to a large net outflow in the mid-1990s. Because this pattern has reached a maximum in the final year of data, it is unclear whether to expect this pattern to continue or reverse in the future.

Figure 17: Variable Internal Migration Model Loadings for Component 2 by Year

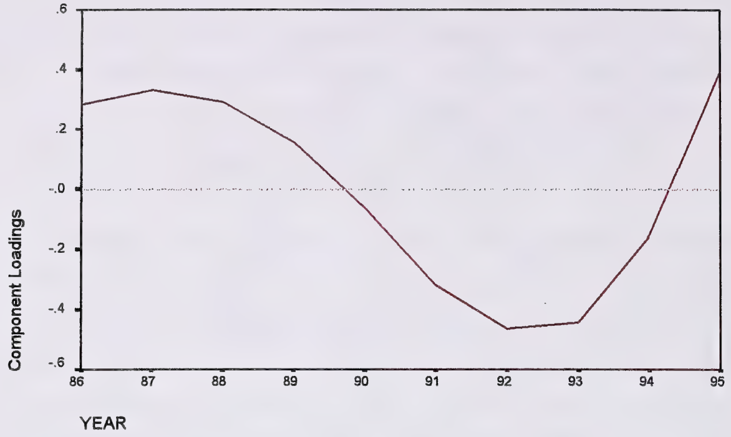
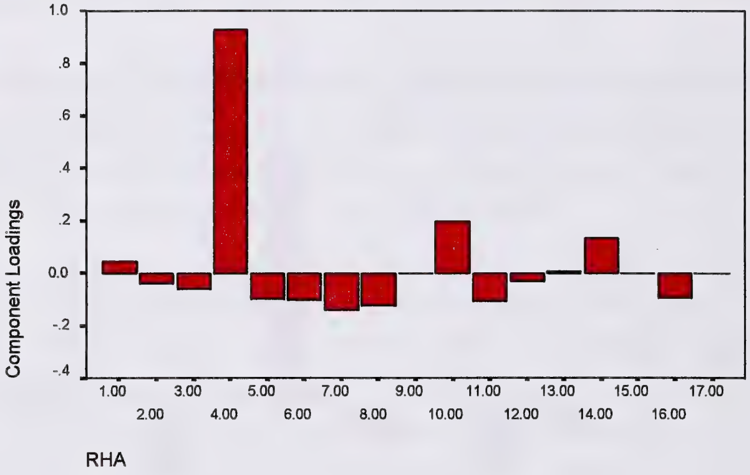


Figure 18: Variable Internal Migration Model Loadings for Component 2 by RHA



Figures 17 and 18 show a component which primarily describes a pattern of internal migration/ reallocation for RHA 4 (Calgary) such that an early net inflow in the late 1980s gave way first to a net outflow in the early 1990s and then to a large net inflow in the mid-1990s. As with the previous component, because this pattern has reached a maximum in the final year of data, it is unclear whether to expect this pattern to continue or reverse in the future.

Overall, these components suggest that temporal trends of migration to the largest Urban areas in the province are relatively unstable over the long term. At present, and in support of the inferences available from the previous analysis of the stable internal migration component, it appears that there is currently a population shift underway between Calgary and Edmonton. The largest flow was in the final year for which data was available, and this makes it virtually impossible to predict whether this trend will continue or whether it will asymptote or even reverse.

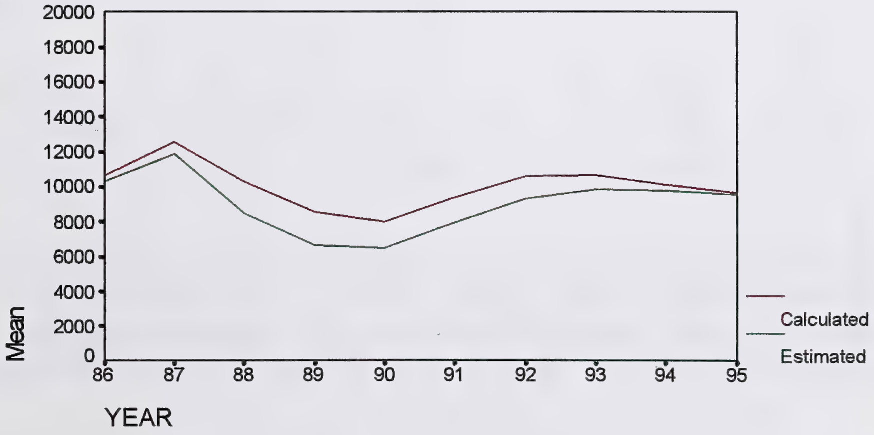
4. Combined Model

To form a final estimate of the full three-way Net Migration table and evaluate the extent to which it fit the original (smoothed) data, the estimates of time varying internal migration were allocated to each age group in proportion to its representation in the Alberta population as a whole.

To summarize, the full model estimates of migration include a component based upon net migration to Alberta for each of the study years proportionally allocated to each RHA, a component for each RHA which is equally allocated to each year in the ten year study period, and a component for each year for each RHA which is allocated across the age groups in proportion to their representation in the Alberta population. These latter components represent both an internal migration between RHAs and 'errors' made in the allocation of in-migrants to (or out-migrants from) the RHA based on the proportional allocation assumption.

The fit of this three component model to the full data array was assessed by correlation. Specifically, the estimates derived by the model correlated 0.97 with the smoothed migration data over all regions over all age groups over all ten years. This represents a strong fit. A second method of assessing the fit of this model is available: net internal migration can be estimated as the sum across all regions of the absolute value of the net migrations into/out of the regions minus the absolute value of the net migration into/out of the province divided by 2 (since each person who migrates from one region to another will appear as a plus for one region and a minus for the other). Figure 19 shows the actual and model predicted internal migration and represents a close approximation, especially for later years.

Figure 19: Actual and Estimated Internal Migration in Alberta 1986-1995

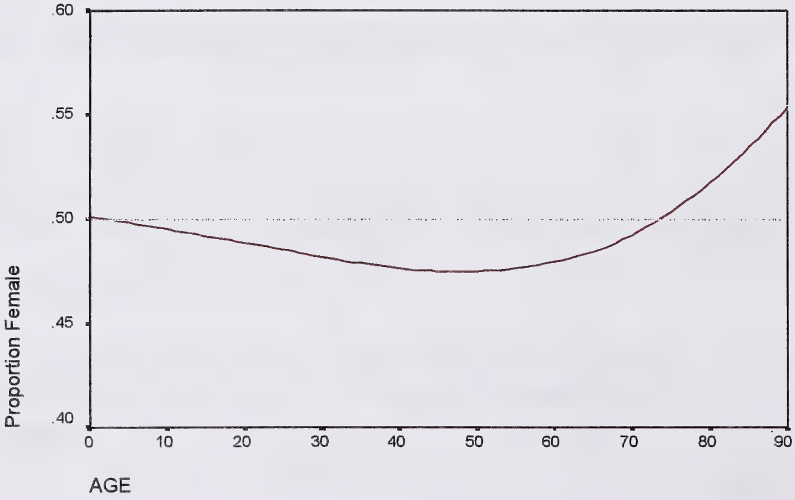


This strong fit of the combined model does not give a strong indication of how to project migration in the future, however, for several reasons: first, the time span modeled is very short and gives little confidence that future trends will be like past ones. In particular, economic trends which have traditionally been associated with Alberta migration typically have longer cycles than can be predicted using 10 years of data. Second, the data indicate that the final year of the current study period was also the one with the highest net in-migration. This may signal the beginning of a new cycle of migration. Third, while it has been demonstrated that the predominant in-migrants have shifted from adults in their early twenties to adults in their later twenties over the study period, it may be imprudent to assume that this trend is a long-term one without additional data. The same may well be said of the apparent excess migration of adults in their later twenties and early thirties to Calgary and corresponding out migration from Edmonton. Fourth, the current ten years do not reflect a net in-migration to RHA 16 which contains major industrial developments associated with the Oil Sands. Given that several expansions and new Oil Sands initiatives have been recently announced, an adjustment of any projection based on the past ten years might be justified for this region.

5. Sex Distribution for the Combined Model

Finally the issue of sex ratios for migrants was solved as follows: (1) the ratios of female to total migrants for the year of age by calendar year data (i.e. summed over regions) were calculated; (2) a singular value decomposition of this table was produced; (3) the first left vector (which shows the age ratios across the ten year period) was smoothed to produce a set of age specific sex ratios; and (4) all migration figures were multiplied by the appropriate estimated ratio to produce separate estimates of female and male migrants. The final ratios are shown in Figure 20 below.

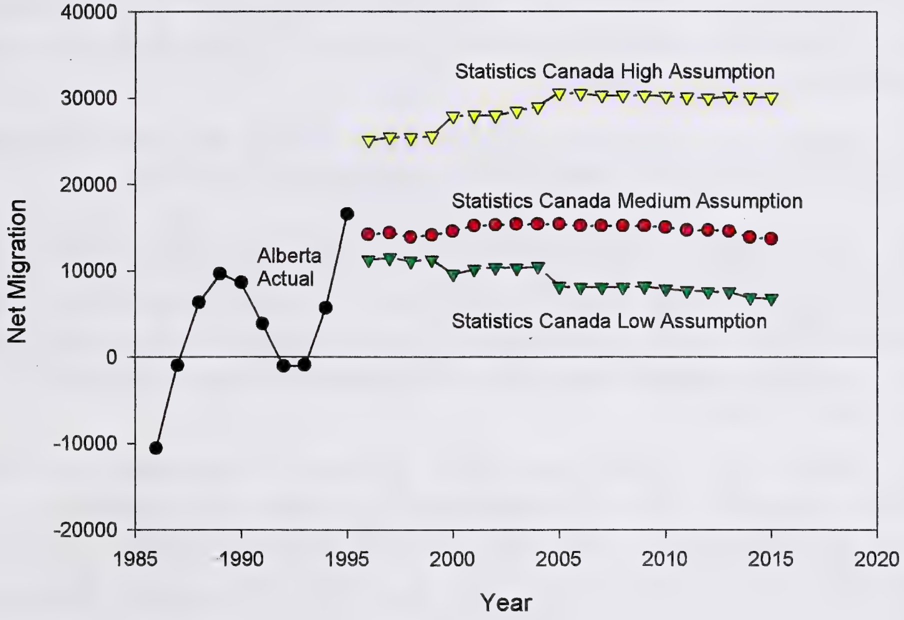
Figure 20: Predicted Proportion of Female migrants by Age 1986-1995



Projections of Future Alberta Migration

The migration component of any population projection model is the most difficult to predict and hence the one for which largest variability between projections and actual figures may be observed. Unlike fertility and mortality which change gradually and smoothly, changes in migration patterns can be very volatile and can reflect short term and emerging economic trends. As a result, migration projections are typically formed on the basis of very long term trends and large population areas. The models developed to describe Alberta Migration from 1986 to 1995 are an inadequate basis upon which to create projections of migration into or out of Alberta for the future, primarily because they are based upon a short period of time and upon small populations. However, the recent Statistics Canada population projections for Canada and the Provinces (Statistics Canada, 1996) report three separate scenarios for Alberta migration based upon global considerations and trends which have occurred over a much larger time frame. These figures are presented in Figure 21 and in Appendix B.

Figure 21: Net Migration to Alberta: Actual and Projected



The current projections use the Statistics Canada scenario figures, but allocate them to age groups and Regional Health Authorities using selected components of the descriptive models presented above. Slight adjustments to these models were made in line with considerations noted in the previous section, and it may prove necessary to update population projections for future years as new information about migration patterns are collected.

Specifically, external migration is first allocated for each of the projection years using the projection figures and the age patterns of the two component model of external migration. Then the migrants are assigned to the Regions in proportion to 1996 population figures. Next the migration is adjusted by the stable internal migration model which allocates internal migration (and misallocations of external migration). Finally, the migration is adjusted by the variable internal migration model.

The adjustments to the migration model for the purposes of projection are described below:

First, examination of the external migration model has suggested that the first component has died away in recent years while the second component has become dominant. For the low and medium assumptions, this pattern will be maintained at current levels (as indicated by the values for the final year of data). However, for the high migration model, it is assumed that the relative importance of the two components of the external migration model will gradually equalize. This is accomplished by gradually lowering the relative importance of component 2 while gradually increasing the relative importance of component 1.

Figure 19 shows that internal migration is stable through the past ten years and consequently it is assumed to remain stable over the projection period.

If migration is moderate or high, it is reasonable to assume that the internal migration from Edmonton (Region 10) to Calgary (Region 4) will be reduced, and consequently this is gradually reduced under the moderate and high assumptions. This is accomplished in two ways: attenuation of the time trends in the variable internal migration model, and gradual attenuation of the relative influence of component 2 in the stable migration model.

Finally, under the high migration assumption, Oil Sands development is expected to play a role in migration. This is accomplished in two ways: by adjusting the relative proportion of individuals who migrate to RHA 16 in the external migration model, and increasing the relative importance of RHA 16 to component 3 of the stable internal migration model as well as the relative importance of this component to overall internal migration.

These adjustments to the model are summarized in Table 1 below.

Table 1: Model adjustments under differing Migration Assumptions

	Provincial Model Component 1	Provincial Model Component 2	Regional Model Component 1	Regional Model Component 2	Regional Model Component 3
Low	stable	stable	stable	stable	stable
Medium	stable	stable	stable	stable	stable
High	stable	increase RHA 16	stable	gradual decrease	increase RHA16

Appendices for Chapter IV

Appendix 4A: Mathematical Representation of the Migration Model

The initial table of Net Migrations NM_{ijk} contains (smoothed) net migrations for an age group to a particular region in a particular year

where i ranges across different years of age from 1..I
j ranges across different regions from 1..J, and
k ranges across different calendar years from 1..K

The final model is represented as

$$NM_{ijk} = C1_{ijk} + C2_{ijk} + C3_{ijk} + e_{ijk} \tag{1}$$

where $C1_{ijk}$, $C2_{ijk}$, and $C3_{ijk}$ are separate additive components derived in successive analyses of NM_{ijk} and its residuals and e_{ijk} is a residual error term.

Note on Notation: In the development to follow, where a quantity is not sub-scripted by a particular index, it is assumed to be constant over all levels of that index.

External Migration

$C1_{ijk}$ is a (sub)model representing external migration to/from Alberta in I age groups over K years allocated to J regions in proportion to their population where

$$C1_{ijk} = \sum_{m=1}^{M}\left(\sum^{I}\sum^{K}\sum^{J} A_{im} * D_m * Y_{km} * R_j\right) \tag{2}$$

The A_{im}, D_m, Y_{km} are derived from a singular value decomposition of the two-way NM_{ik} table (derived by aggregating over the j levels of region.) The summation over M indicates the M separate additive components of the decomposition required to reproduce the NM_{ik} to a desired level of accuracy. The size of the D_m indicates the relative importance of the component.

The R_j in equation (2) are derived as $\sum^{I}\sum^{K} P_{ijk} / \sum^{I}\sum^{J}\sum^{K} P_{ijk}$ where P_{ijk} is the population at age i in region j in year k. The R_j are considered constant across i and k for each region.

Note on singular value decomposition: Using the notation of linear algebra, a rectangular table M_{ij} is decomposed into the product of three matrices

$$M_{ij}=L_{ik}\,D_{kk}\,R'_{kj} \qquad (3)$$

where L and R are orthonormal (the vectors in each matrix are pair-wise orthogonal (at right angles) and each have unit lengths) and D is diagonal. In a full decomposition, k= min(i,j). When the matrices are ordered such that the values in D are decreasing, the singular value decomposition of a table produces successive components which describe orthogonal contributions to the data variation in the full table starting with the component which describes the largest amount of this variation. A model with k <<min(i,j) which adequately reproduces the original table can be interpreted as a model of the underlying structure of the table. The singular value decomposition is a least-squares procedure, and has close relationships to principal component analysis and other multivariate and multivariable methods. The entries in the R matrix and those in the L matrix can be examined in relation to natural orderings in the dimensions of the table (e.g. year-of-age, calendar year) to describe patterns of variation. For further detail see e.g. Green 1980.

Internal Migration/Reallocation

After the estimates $C1_{ijk}$ have been developed, the residual matrix $RES1_{ijk} = NM_{ijk} - C1_{ijk}$ is formed. To analyze these residuals a two-way table $R1_{ij}$ is formed by aggregating over the K years. $C2_{ijk}$ is a (sub)model representing internal migration/reallocation between the J regions for the I age groups allocated to each of the K years equally.

$$C2_{ijk} = \sum_{m=1}^{M}\left(\sum^{I}\sum^{J}\sum^{K} A_{im} * D_m * R_{jm} * Y_k\right) \qquad (4)$$

The A_{im} , D_m, R_{jm} are derived from a singular value decomposition of the two-way $R1_{ij}$ table. The summation over M indicates M separate additive components of the decomposition. The Y_k in equation (4) are derived as $1/K$.

Time Trend in Internal Migration/Reallocation

After the estimates $C2_{ijk}$ have been developed, the residual matrix $RES2_{ijk} = NM_{ijk} - C1_{ijk} - C2_{ijk}$ is formed. To analyze these residuals a two-way table $R2_{jk}$ is formed by aggregating over the I age groups. $C3_{ijk}$ is a (sub)model representing internal migration/reallocation between the J regions for the K years allocated to the I age groups in proportion to their distribution in Alberta as a whole.

$$C3_{ijk} = \sum_{m=1}^{M}\left(\sum^{K}\sum^{J}\sum^{I} R_{jm} * D_{m} * Y_{km} * A_{i}\right) \qquad (5)$$

The R_{jm} , D_{m}, Y_{km} are derived from a singular value decomposition of the two-way $R2_{ij}$ table. The summation over M indicates M separate additive components of the decomposition. The A_{i} in equation (4) are derived as $\sum^{J}\sum^{K} N_{ijk} / \sum^{I}\sum^{J}\sum^{K} N_{ijk}$ where N_{ijk} is the population at age i in region j in year k. The A_{i} are considered constant across j and k for each region and year.

Appendix 4B

Statistics Canada Migration Projections for Alberta 1996-2016

Year	Low Migration	Medium Migration	High Migration
1996-97	11300	14200	25100
1997-98	11500	14400	25500
1998-99	11100	13900	25400
1999-00	11300	14100	25600
2000-01	9600	14600	27900
2001-02	10200	15200	28000
2002-03	10400	15300	28000
2003-04	10300	15400	28500
2004-05	10500	15400	29000
2005-06	8200	15400	30600
2006-07	8100	15200	30500
2007-08	8100	15200	30300
2008-09	8100	15200	30300
2009-10	8200	15200	30300
2010-11	7900	15000	30200
2011-12	7700	14700	30100
2012-13	7600	14700	30000
2013-14	7600	14600	30200
2014-15	6900	13900	30100
2015-16	6800	13700	30100

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